A WEB-BASED LEARNING SUPPORT SYSTEM FOR INQUIRY-BASED LEARNING USING TREASURE HUNT

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Abstract

Web-based learning has become a very popular learning mechanism. However, Web-based learning may not always work effectively, and sometimes fails to meet its learning objectives. Students frequently express dissatisfaction with Web-based learning suggesting it is "hard to stay motivated." Learning games offering challenges and entertainment may stimulate and motivate students to learn. Nevertheless, no empirical evidence proposes learning games will promote student learning without instructional activities.

Web-based learning support systems enable students, who are taking courses in which the systems are involved, to learn topics. Web-based learning support systems, combined with learning games, are able to efficiently promote learning by encouraging student participation. Inquiry-based learning is a student-centered educational method driven more by student questions than by an instructor's lessons. Web-based learning support systems will hopefully take the idea of inquiry-based learning and combine the learning games in a way to maximize the effectiveness of learning.

In this thesis, we present a Web-based learning support system called OTHI - Online Treasure Hunt for Inquiry-Based Learning. The system is designed according to a treasure hunt model, which embodies the idea of inquiry-based learning using set theory. Its implementation exploits some open source softwares and off-the-shelf extensions, and uses not only Web technology but also online game technology by including a development of an online treasure hunt game as the learning game. We also address the implementation and demonstration of the system with a data communications and network course, and discuss its usefulness for supporting students' learning activities. This Web-based learning support system is able to provide students with an inquiry-based learning environment in which they actively partake in learning.

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Dedication

I would like to give my sincerest thanks to my precious wife, Bookhee, and my wonderful daughters – Soyoung, Sunyoung and Seyoung – for their love, support, understanding, and sacrifices. I also dedicate this work and give special thanks to my parents and brothers for their understanding and encouragement during my studies.

Acronyms

IBL	Inquiry-Based Learning
LSS	Learning Support Subsystem
NPC	Non-Player Character
OTHI	Online Treasure Hunt for Inquiry-Based Learning
PAWL	Passive Asynchronous Web-based Learning
SOLC	Sun Open Learning Center
TFCL	Traditional Face-to-face Classroom Learning
TSS	Teaching Support Subsystem
WLSS	Web-based learning support systems

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Chapter 1

Introduction

The Internet has emerged as a major, and perhaps eventually the major worldwide communication channel for information, knowledge and services [15]. The impact of the Internet can be seen in all aspects of people's lives. Its impact on teaching and learning may be even greater. The Internet has led to advances in computer technologies, especially in World Wide Web technology. The advances in Web technology have shifted the paradigm of education from the traditional teacher-centered model to a collaborative student-centered model [22].

Web-based learning is growing in popularity and offers many benefits over traditional learning environments [21, 84]. The Web provides a distributed infrastructure for information processing, with global accessibility, and a user-friendly interface [82]. Web-based learning delivers various forms of learning content such as text, audio, graphics, animation and video, with reasonable prices through the Web. It increases opportunities for education [31].

However, students may passively take part in online classes which lack interaction with the learning material [37] and furnish inflexible instruction without consideration for each student's background knowledge [21]. In addition, many online learning systems do not request that instructors simultaneously participate in their students' learning process. This results in a lack of interaction between students and instructors [85]. This passive, asynchronous Web-based learning makes it difficult for students to remain motivated and continue learning.

Digital games may be applied to reduce the negative feedback of Web-based learning when dealing with a lack of motivation for learning [33]. Digital games hold players' attention and stimulate their internal motivation [30]. The aim of a rational player is to win the game or to be one of the top players in the game. *Playing* implies active participation. That is, the game must be *player-centered*, and at every opportunity, players need to make their own decisions to win the game. Students require this type of motivation in their learning. Jong *et al.* [33] investigated student perception of a game-based learning method with traditional Web-based learning. They found game-based learning was far more favored, more interesting, more explanatory, more stimulating, more challenging, and more capable of empowering students to learn with confidence and retain learned knowledge in their mind.

Learning support systems not only enhance student learning, but also motivate students to learn [63]. The recent development of the Web has increased the need to move traditional computerized support systems to the Web platform and enhance support systems into further user-friendly systems [82]. Web-based learning support systems (WLSS) are computerized learning support systems redesigned or modified to use Web technology to support student learning [79]. Students may not only eliminate study difficulties, but may also be encouraged to learn with the support of WLSS.

The goal of this research is to design and implement a Web-based learning support system which mitigates the limitations of Web-based learning and encourages active student participation in learning by using an online-learning game. As for the design of such a Web-based learning support system, it is necessary to discuss the integration of the online-learning game into the system in a way which maximizes the effectiveness of learning. The effectiveness could be improved if game-based learning was combined with traditional teaching approaches [33]. Moreover, games combined with student-centered teaching approaches are more effective and attractive than games with basic drill-and-practice approaches [36].

Inquiry-Based Learning (IBL) is an educational approach driven more by student questions than by the instructor's lessons, and involves active, student-centered learning [18, 22]. Lim [41] described Web-based learning environments, designed with IBL, as providing students with cognitive tools and helping them form a learning community in which instructors and students interact to solve complex problems. IBL is compatible with constructivist learning strategies [43]. In constructivism, knowledge is defined as the cognitive structure of a person and learning is the active process of *constructing knowledge* rather than the process of knowledge acquisition [39]. In IBL, students construct knowledge using an inquiry approach [74].

The thesis will present a Web-based learning support system called *OTHI*, which stands for Online Treasure Hunt for Inquiry-Based Learning. The system design is based on a treasure hunt model, which takes its inspiration from a treasure hunt as a method to apply IBL to the system and embodies the idea of IBL using set theory. The Web-based learning support system takes advantage of online game technology as well as Web technology in its implementation. *OTHI* employs an online treasure hunt game in which students conduct a *treasure hunt* on a certain topic and develop an answer to a given question, and includes a website to support instructors and students who utilize the online treasure hunt game for student learning. Some open source softwares and off-the-shelf extensions are used to implement the system. With this system, students are able to experience IBL and study the course topics in an enjoyable and interesting way.

This thesis is organized as follows: Chapter 2 describes background information regarding Web-based learning, WLSS, Web technologies and IBL, and presents the problem statement; Chapter 3 defines learning order relationship and its knowledge spaces, and depicts a treasure hunt and a treasure hunt model; Chapter 4 details several algorithms for two major functions of OTHI, describes the implementation of a prototype of OTHI, demonstrates the prototype system with a data communications and network course, and discusses the usefulness of OTHI in student learning; and Chapter 5 gives the concluding remarks, the summary of contributions and directions for future research.

Chapter 2

Background Information

Chapter 2 offers some background information and technologies upon which this thesis is based. A detailed review of Web-based learning is provided, including student-centric learning, online courses and an example of Web-based learning. An overview of WLSS is also presented, with discussion of Web technologies such as Web search engines, Web services and online-learning games utilized to implement WLSS. In addition, the chapter provides an in-depth overview of IBL, including IBL processes and a Web-enabled IBL model. At the end of this chapter, a problem statement is presented with a brief discussion of a new approach.

2.1 A Review of Web-Based Learning

This section gives a detailed review of Web-based learning, including student-centric learning, online courses and an example of Web-based learning: Sun Open Learning Center (SOLC).

2.1.1 Web-Based Learning

The Web is a popular medium for storing, presenting, gathering, sharing, processing and using information [82]. The Web offers the following benefits for learning: 1) it provides a distributed infrastructure of educational content; 2) it can be used as a channel in which students collaborate and interact; 3) it delivers various forms of learning content and secure information in a timely manner; 4) it provides a student-friendly interface; 5) there are no time frames or geographic restrictions when attending online classes; and 6) it can remotely and instantly manage and retrieve knowledge.

Web-based learning is sometimes called *online learning* or *e-Learning* since it includes online course content [48]. The content may consist of various forms of multimedia like audio, graphics, animation and video. It not only enhances an individual's problem-solving skills, but also motivates students to complete a task by the vividness of the presentation [85].

In addition to the student-friendly and eye-catching content, Web-based learning eliminates the barriers of time and geographical distance in education [31, 85]. Once the learning content is created, students can use the content at anytime, anywhere. Wherever students are located, they can take part in their online classes as long as the Internet is available [85]. It also allows students to take courses in a cost effective learning environment [21, 31]. Web-based learning gives many people a second chance to educate themselves [31].

2.1.2 Student-Centric Learning

Modern-day learning is shifting from teacher-centric to student-centric, which emphasizes relevance, personalization and learning flexibility [85]. Traditional education provides a teacher-centered form of education and group learning in a conventional classroom [21]. A typical scenario of a traditional class involves a teacher instructing students, and students listening to the teacher and taking notes. This face-to-face learning has the advantage of being familiar and close, and is comfortable for both the teacher and students [85].

However, it is almost impossible for a teacher to satisfy all requirements of all students with his/her lecture allotment. Normally, a lecture is prepared for average students with an average background knowledge of a lecture topic. It is also very difficult to measure each student's understanding of the class, even though the teacher takes into account student feedback (quizzes, exams and assignments) in the lecture. One barrier for traditional education is learning basically depends on limited time and a fixed place.

Alternatively, Web-based learning can provide a student-centered form of education, and self-directed, individual learning [21]. A student can choose the most suitable course for themself, based on his/her background knowledge. The student can replay learning materials until (s)he feels satisfied, or by-pass those materials with which (s)he is already familiar. If the student has questions in his/her online class, (s)he can easily receive assistance from groups of teachers and other students by using a communication tool supplied by the Web-based learning system which manages the online class. The student can determine his/her understanding of the class by using various types of tests at any time. Therefore, Web-based learning is considered as one means of reducing the disadvantages portrayed by traditional methods of learning.

2.1.3 Online Courses

Nowadays, many universities worldwide are offering thousands of online courses, including degree and certificate programs [37, 85]. Table 2.1 provides a list of U.S. universities offering online courses. As of 2009, Stanford University has 23 master of science degrees, completed entirely online. The University of California offers more

Schools	**Courses or programs**
University of Phoenix (http://www.phoenix.edu)	Arts and Sciences, Business and Management, Criminal Justice and Security, Education, Human Services, Nursing and Health Care, Psychology, Technology.
Stanford University (http://scpd.stanford.edu)	Aeronautics and Astronautics, Bioengineering, Biomedical Informatics, Civil and Environmental Engineering, Computer Science, Computational and Mathematical Engineering, etc.
University of California, Berkeley (http://explore.berkeley.edu)	Art and Design, Behavioral and Health Sciences, Basic Sciences, Business and Management, Computer Technology and IS, Education, Electronic Engineering, Humanities, etc.
Georgia Institute of Technology (http://www.dlpe.gatech.edu/dl)	Aerospace Engineering, Computational Science and Engineering, Electrical and Computer Engineering, Environmental Engineering, Industrial Engineering, Mechanical Engineering, etc.
University of Illinois Online, Urbana (http://www.online.uillinois.edu)	Agricultural Business and Production, Biological Sciences and Life Sciences, Business Management and Administrative Services, Communications, etc.
New Jersey Institute of Technology (http://adultlearner.njit.edu)	Architecture, Computer Science, Information Systems, Information Technology, Construction Management, Emergency Management, Engineering Management, Environmental Science, etc.
Columbia University, New York (http://ci.columbia.edu/ci/ecourses)	Business and Finance, Education, Engineering and Applied Science, Medicine, Philosophy and Religion.
University of Colorado Denver (http://www.cudenver.edu/Academics /CUOnline)	Sociology, English Writing, Nursing, eLearning, School Library, Early Childhood Education, Business Administration, Geographic Information Systems, Public Administration, etc.

Table 2.1: Examples of U.S. universities offering online courses.

Companies	**Web-based learning solutions**
Cisco Systems (https://cisco.hosted.jivesoftware.com)	Cisco Learning Network
Dell (http://www.learndell.com/dls)	Dell Learning System
Hewlett Packard (https://www.rooms.hp.com)	HP Virtual Classroom
IBM (http://www.ibm.com/training/us/ilo)	IBM Instructor-led Online
Microsoft (https://www.microsoftelearning.com)	Microsoft E-Learning
SAP (http://www.sap.com/usa/services/education)	SAP Education E-Learning, Virtual Live Classroom
Sun Microsystems (http://www.sun.com/training/elearning)	Web-based Training, Live Virtual Class

Table 2.2: Examples of IT companies providing online courses.

than 140 courses through Web-based learning. The University of Colorado, Denver offers 340 courses and 14 degrees available online.

Meanwhile, companies have widely adopted Web-based learning solutions for their corporate training (See Table 2.2). The solutions allow individual employees to have learning-on-demand opportunities while reducing training time and costs [85]. The companies offer their Web-based learning solutions not only to employees, but also customers, as a training service. As listed in Table 2.3, many other companies such as Ninth House, Cengage Learning, Tutorials.com, SkillSoft and Kaplan Financial

Companies	**URL**
Cengage Learning	`http://cengage.co.uk`
Kaplan Financial Education	`http://www.kfeducation.com`
Ninth House	`http://ninthhouse.com`
SkillSoft	`http://skillsoft.com`
Tutorials.com	`http://tutorials.com`

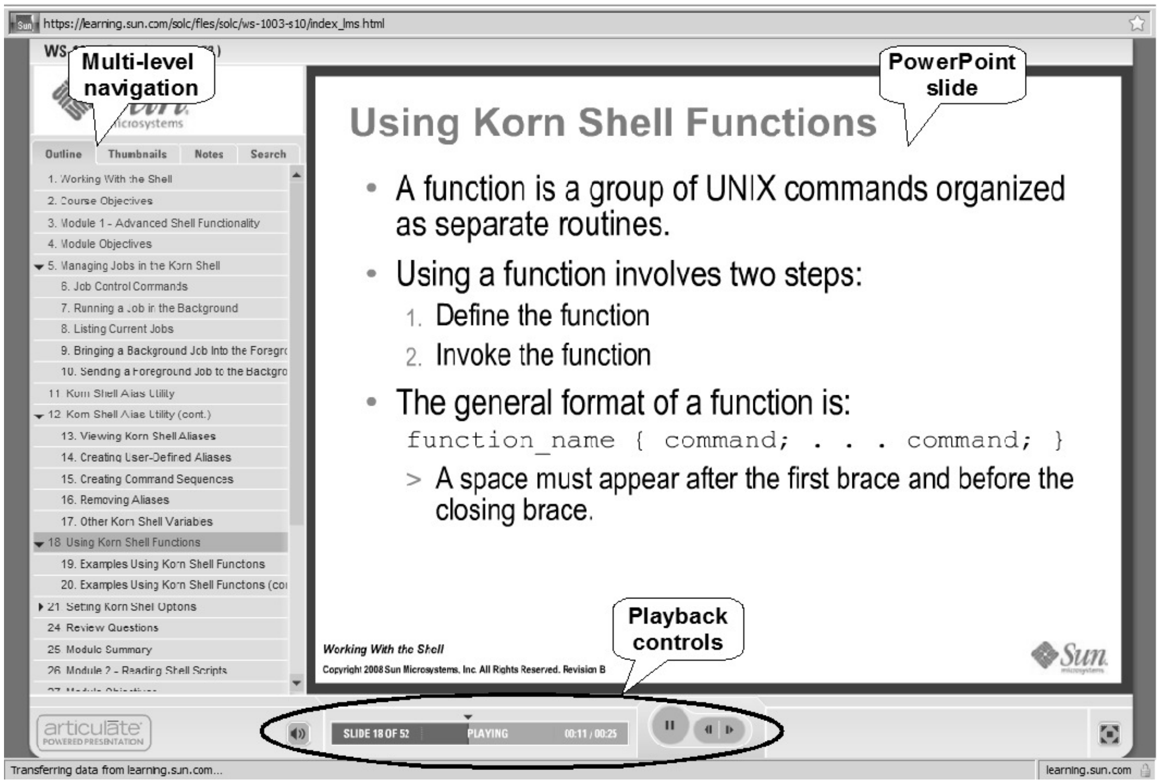
Table 2.3: Examples of companies providing online learning services.

Education, provide Web-based learning services.

2.1.4 An Example of Web-based Learning: SOLC

Sun Open Learning Center (SOLC) (`http://www.sun.com/training/solc`) represents a typical form of Web-based learning providing online courses about OpenSolaris and Sun Solaris. It is free to anyone who has a Sun account. The two courses available for Sun Solaris are: Introduction to Solaris and Intermediate Solaris. Managing ZFS Pools and OpenSolaris Labs Sandbox courses are available for OpenSolaris. Introduction to Solaris course topics include: Using Components of the Desktop System, Manipulating and Managing Files and Directories, Searching and Process Manipulation, Working with the Shell, and Archiving Files and Remote Transfer. Intermediate Solaris course topics include: Booting SPARC and x86 Based Systems, Controlling System Processes, Create and Manage Users, Installing Solaris 10, etc. Students may choose a course with no prerequisites.

A SOLC course may consist of up to five components: a presentation, a quiz game, an open question, supporting documents and lab exercises. Figure 2.1 depicts a presentation regarding a topic belonging to the Introduction to Solaris course. The presentation mainly contains PowerPoint slides, multi-level navigation and playback controls. A PowerPoint slide explains a *sub-topic* with text information, images and voice narration. The multi-level navigation has four levels: Outline, Thumbnails, Notes and Search. The names of the PowerPoint slides are displayed in a hierarchical order in the Outline. By simply left clicking on a slide name, students are taken to



https://learning.sun.com/solc/files/solc/ws-1003-s10/index_lms.html

1. Working With the Shell
2. Course Objectives
3. Module 1 - Advanced Shell Functionality
4. Module Objectives
5. Managing Jobs in the Korn Shell
   6. Job Control Commands
   7. Running a Job in the Background
   8. Listing Current Jobs
   9. Bringing a Background Job Into the Foregr
   10. Sending a Foreground Job to the Backgro
11. Korn Shell Alias Utility
12. Korn Shell Alias Utility (cont.)
   13. Viewing Korn Shell Aliases
   14. Creating User-Defined Aliases
   15. Creating Command Sequences
   16. Removing Aliases
   17. Other Korn Shell Variables
18. Using Korn Shell Functions
   19. Examples Using Korn Shell Functions
   20. Examples Using Korn Shell Functions (co
21. Setting Korn Shell Options
24. Review Questions
25. Module Summary
26. Module 2 - Reading Shell Scripts

Using Korn Shell Functions

- A function is a group of UNIX commands organized as separate routines.
- Using a function involves two steps:
  1. Define the function
  2. Invoke the function
- The general format of a function is:

```
function_name { command; . . . command; }
```

> A space must appear after the first brace and before the closing brace.

Working With the Shell
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Transferring data from learning.sun.com...

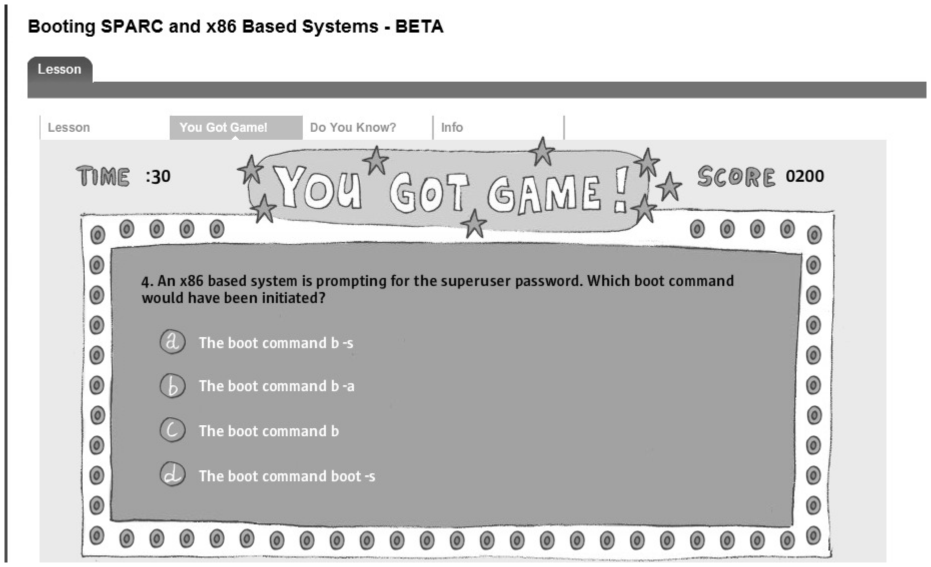
learning.sun.com

Figure 2.1: Presentation of Sun Open Learning Center.

the PowerPoint slide without interruption. The *Thumbnails* represent small versions of the PowerPoint slides. The *Notes* show a description of a voice narration. The *Search* lists the names of PowerPoint slides containing a specific word. They can move to the next slide or the previous slide and control the voice narration by using the playback controls.

The quiz game provides students with four quizzes to do with a topic they have learned. As depicted in Figure 2.2, it displays available time and scores in the upper left-hand corner and in the upper right-hand corner, respectively. Students need to answer the four quizzes within 45 seconds by choosing the right answer from the four answers. Voice narration is also provided with each quiz.

As for the open question, students are requested to explain what they know about



Booting SPARC and x86 Based Systems - BETA

4. An x86 based system is prompting for the superuser password. Which boot command would have been initiated?

a. The boot command b -s

b. The boot command b -a

c. The boot command b

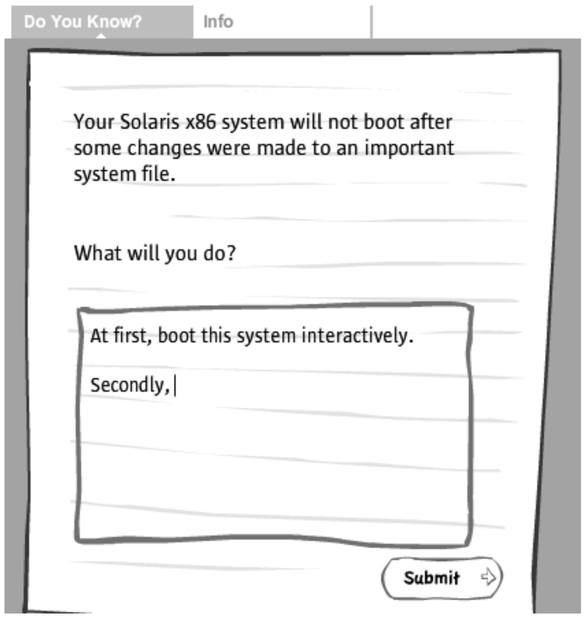
d. The boot command boot -s

Figure 2.2: Quiz game of Sun Open Learning Center.

a given question as they click the tab "Do You Know?" in Figure 2.2. Figure 2.3 shows an example of an open question. When students submit an answer to a question, the system shows its Expert Answer with no marks given for the answer. When they click the tab "Info" in Figure 2.3, it presents a list of hypertext links pointing to Web documents which relate to the topic.

Students are able to get access a virtual lab environment with lab exercises and *asynchronous* support from an instructor upon buying a Sun on-demand lab. It enables students to master key skills by completing real world lab exercises at a virtual lab. On the other hand, SOLC offers OpenSolaris Learning Cloud Service which allows students to freely try the features of OpenSolaris for one hour. The lab desktop of the OpenSolaris Learning Cloud Service gives students access to a virtual desktop where they can complete lab exercises for the OpenSolaris operating system.

The SOLC has some drawbacks in terms of learning. Many of the course topics have several sub-topics. A one-time presentation of the course covers all sub-topics related to a main topic and requires students to spend a lengthy amount of time



Your Solaris x86 system will not boot after some changes were made to an important system file.

What will you do?

At first, boot this system interactively.

Secondly,

Figure 2.3: Open question from the Sun Open Learning Center.

and attention on the presentation, sitting in one spot without *interactivity*. Students cannot be expected to comprehend all the sub-topics the presentation contains in one sitting.

Students may enjoy the quiz game and see the Expert Answer to the open question before completing the presentation, since all four quizzes and the one open question do not interfere with them easily catching the main ideas of the topic. However, students cannot expect such learning activities from other courses which consist of only the presentation. Although the courses offer the quiz game and question, four quizzes and one open question are not enough to review all the sub-topics.

Students will not be aware of other students' learning performance and there is no way of measuring their progress in a course. Furthermore, there are no features which allow students, who are taking the same courses, to contact each other. Hence, it is difficult to share ideas and issues regarding the learning topics with other students.

2.2 An Overview of Web-based Learning Support Systems

Web-based learning support systems (WLSS) assist, support, and aid students with learning activities. WLSS can be utilized to mitigate problems students have in conventional classrooms, even with online courses. Furthermore, Web-based learning may also receive support from WLSS to solve unforeseen problems. In this section, an overview of WLSS is presented in order to further investigate any possible solutions WLSS may provide.

2.2.1 Web-based Learning Support Systems

WLSS support instructors and students to achieve better teaching and learning outcomes [21]. *Web technology* refers to all technologies which implement, maintain, and use the Web. Advances in the Web technology remove any barriers of time and place for supporting various human activities and generate further momentum for the design and implementation of computerized support systems [82].

Web-based support systems [80] take advantage of Web technology to provide further user-friendly support environments [82]. The most popular and successful computerized support systems are decision support systems. If people develop decision support systems using Web technology, those systems become Web-based decision support systems [57]. Likewise, if people take into account learning, computerized learning support systems combined with Web technology can be intuitively called Web-based learning support systems [79]. As represented in Figure 2.4, any Web-based system which contributes to students' learning can be viewed as a WLSS.

Fan and Yao [21] described the main features of WLSS for the implementation of student-centered learning environments. The main features include: encouraging students to communicate with each other; delivering adapted learning content based on students' background knowledge; providing an interactive interface; and evaluating

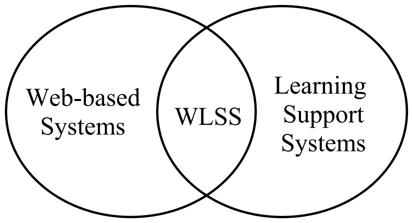


Figure 2.4: WLSS, the intersection of Web-based systems and learning support systems.

students' learning process. They also presented three views in terms of the design of WLSS, namely teacher, student and administrator views. Teachers consider WLSS to be convenient tools to create and modify learning content, while students regard WLSS as learning support tools containing a variety of learning content. Administrators might use WLSS to maintain the systems.

Pinkwart *et al.* [55] expressed four support criteria of WLSS: learning process support, community support, task support, and organizational support. They applied the criteria to an implementation of a WLSS called *iPAL* (Internet Portal to Augment Learning) system, which extends a freely available *content management system* for learning via necessary off-the-shelf extensions and several self-developed modules.

Hirai and Hazeyama [29] developed a WLSS, called *Concerto*, and applied it to an actual university course. The system focuses on question-posing by students, and supports not only question-posing and assessment of questions posed among peers, but also discussions about the questions. The experimental result of the system showed the exchange of questions and answers between students contributed to an improvement in understanding as to what they had learned.

2.2.2 Architecture of Web-based Learning Support Systems

Generally, WLSS architecture forms a thin-client and server structure in which enterprise-wide applications, installed on a server, are available to multiple users using client softwares. The client software is responsible for transmitting input and output messages between the remote server and the user, while the server performs requested computing services as a database server, an application server, a file server, or a Web server. The server also sends back a response to the client software to present a processing result, indicating a confirmation of completion of the requested operation, or giving a notice of a failure of an operation.

WLSS have a web browser with plug-in modules to work as the client software. Web programs are placed and executed in the Web server, and communicate with a database management system or other programs. The web browser provides an interface between the Web programs and the user. A processing result of the Web programs is finally presented through the web browser to the user; the user gives feedback on the result to the Web programs using the web browser.

WLSS architecture also presents a three-layered architecture proposed by Yao and Yao [82]. The three-layered architecture includes an interface and presentation layer, a data layer and a management layer. The interface and presentation layer is located on the top of the architecture. This layer presents and permits interaction with information in a variety of visual and audio formats, and supports communication and expression through a web browser.

The data layer is placed on the bottom of the architecture, and represents knowledge bases, as well as databases. This layer is responsible for storing and manipulating large quantities of information. The management layer of the architecture is located between the interface and presentation and data layers, and serves as the middleware of the three-tier client and server architecture. The management layer performs complex computations with data taken from the data layer in order to process user requests received from the interface and presentation layer.

2.3 Web Technologies Supporting WLSS

This section describes several Web technologies used to build WLSS, such as Web search engines, Web Services and online-learning games. Those technologies may empower WLSS and extend the availability of WLSS. This research takes advantage of those technologies in order to achieve its goal.

2.3.1 Web Search Engines

There are many Internet-enabled applications and services. One of the primary tasks of the Internet is for information retrieval and information seeking [25]. Hundreds of millions of Web pages are available on the Internet and connected by hypertext links. People find a particular nugget of information required to fulfill some need they have in the use of the Internet [7]. Without search engines, a vast amount of information on the Internet would be quite interesting but perhaps not very useful [25, 53].

Web search engines have three major functions: collecting new information, collating and extracting useful information, and presenting it in a publicly available Web interface [46]. Information is collected by intelligent agents such as *spiders* crawling over Web pages via connecting links. All documents, found by the intelligent agents, are converted and saved in databases in forms a computer can understand and process. Each collected document is then passed through an information extraction system to extract document representatives and bibliographic information to form indexes [46]. The indexes will be grouped based on the *similarity* of the documents. The search engines entertain user queries and provide a list of relevant documents, in a user-friendly format.

Citation indexing, implemented firstly in 1963 by Garfield [47], is today one of the standard indexing techniques. The citation index indicates how many academic papers were cited from other papers. It reveals relationships between papers, and represents the relative importance of each paper. That is, the more citation numbers a paper has, the more importance is attributed to the paper. *Google* believes every hyperlink embedded in a Web page is a citation to the other Web page [7]. The PageRank system, used by *Google*, shows how many Web pages and sites link to a page. It reflects the relative importance of a site. The *Google* system performs a type of full text search which looks for keywords within the title, abstract, and full text of an article. PageRank bares a very important role in the system to prioritize the results of Web keyword searches [5]. The PageRank algorithm enables *Google* to dominate other Web search engines in terms of usage [79].

The Web is considered to be a large and searchable virtual library and an information resource for scientists, researchers and students [81]. Web search engines make it possible for students to access the virtual library and provide students with information relevant to their topics, in order to improve student learning performance.

2.3.2 Web Services

Web services are considered an emerging web technology. They are self-contained, self-describing, modular applications operating over the Internet. In the development of Web services, the same technical standards are applied to self-description, publication, location, communication, invocation, and data exchange capabilities. It increases the interoperability and reusability of Web-based applications and, as well, greatly reduces the time and effort spent on implementing the applications. The field of online learning may benefit from the advantage of Web services [34], especially Web services which can be combined together to implement a WLSS.

Google Calendar is a Web service provided by *Google* and allows applications to read and update calendar events using Google Calendar Data API. A client application is able to use the Google Calendar Data API to create new events, edit or delete existing events, and query events matching particular criteria [24]. The Google Calendar is a useful coordination tool for students to make appointments with other colleagues and manage their schedules to work together [52].

MetaWeblog API is an application programming interface which enables the implementation of blog-based web services by allowing applications to publish and update the content and attributes of weblog posts [40]. A *weblog* (usually shortened to blog) offers an excellent new channel for discussion, communication and collaboration not only in research [78], but also in learning. Furthermore, *blogs* enable students to develop a deep understanding of, and take more responsibility for, their own knowledge [70].

2.3.3 Online-Learning Games

Modern digital games provide young people with learning opportunities every second and motivate students to learn [58]. Recently, game-based learning has been adopted for adult education, as well as children's learning [16]. It is reported online-learning games are more effective than standalone learning applications, encouraging collaborative learning [9, 34].

Online games are highly graphical 2- or 3-dimensional video games played over the Internet [67]. Players, through their self-created digital characters or avatars, are allowed to interact not only with Non-Player Characters, which are computer-controlled characters, but with other players' avatars. *Online-learning games* are derived from an attempt to not only bring the concept of the online games to interactive learning tools, but also provide students with learning experience through the online games.

Dziabenko *et al.* [16] implemented an online-learning game called "UNIGAME: Social Skills and Knowledge Training." The game is accessible through its website, which furnishes the following features: training and help, community area, user registration, game introduction, virtual conference etc. They believed the game would be used as a complement to lectures or as a standalone learning process, enabling students to better understand the theory as they practically apply it.

Michaelson *et al.* [51] developed an online-learning game for finance education of undergraduates in the FINESSE project. The aim of the game is to provide students with a Web-based learning environment to manage a portfolio of securities with real-time share price data. Shang *et al.* [62] developed an online-learning game called FARMTASIA, a farming simulation game, using the learning framework VISOLE. This framework shows three stages to facilitate students' learning as follows: scaffolding learning, student game-based learning, and debriefing and reflection.

Global Goonzu [23] is a Massively Multiplayer Online Role-Playing Game simulating real world society. A player can experience this world as a warrior, merchant or politician. Its free market economic system enables players to experience real-time trading stock, real estate and other goods. Furthermore, players can take part in the shareholder election, to elect or to become a town chief. Although the game has been developed for fun, it is very useful in the areas of economics and political education.

Childress and Braswell [9] described current uses of multiplayer online games in learning. They derived a process of using multiplayer online games for cooperative learning activities from their experiences in Second Life [61], a Massively Multiplayer Online Role-Playing Game. They also emphasized multiplayer online games can provide students with many meaningful and enriching learning experiences, and the virtual environments of the games enable instructors to easily and efficiently design highly-social cooperative learning activities.

2.4 An Overview of Inquiry-Based Learning

This section presents an overview of inquiry-based learning (IBL) including IBL processes and a Web-enabled IBL model, WebQuest. IBL requires active student participation through an inquiry activity. The IBL process represents an inquiry activity containing the following four phases: presenting phase, retrieving phase, developing phase and evaluating phase.

2.4.1 Inquiry-Based Learning

Inquiry-Based Learning is a student-centered instructional approach in which students seek truth, information, or knowledge by asking questions [8, 22]. IBL enables students to conduct self-directed investigations of problems and issues presented to them [41]. Russell [59] described inquiry as an investigation of a certain problem. Fleissner *et al.* [22] defined inquiry "as a seeking for truth, information, or knowledge; that is, seeking information by questioning." Chan [8] described students constructing their perspectives of natural and human-designed worlds through inquiry activities.

The educational philosophy of IBL is founded on the ideals and principles of constructivism [43]. In constructivism, knowledge is defined as the cognitive structure of a student [39]. The cognitive structure is changed, reconstructed and reorganized by the student's experience [54]. The constructivist believes students are the center of education, and learning is the product of self-organization and reorganization of the cognitive structure of the students [43, 77].

In other words, learning is an active, constructive process rather than process of knowledge acquisition, and teaching is the support of students' constructive processing of understanding rather than the delivery of information to the students [39]. In addition, learning outcomes do not depend on what an instructor presents, but rather upon what information is encountered and how students process it, based on preconceived notions and existing personal knowledge [77]. Inquiry, in constructivist teaching, offers an opportunity to better understand facts and formulas, and encourages student participation in learning [41, 39].

2.4.2 Processes of Inquiry-Based Learning

Edelson [17] presented a three-step model of IBL: a motivational step, an acquire step and a refine step. Each step has activity strategies. The motivational step involves creating a demand for knowledge and eliciting curiosity. The acquire step allows students to discover new knowledge and receive knowledge from others. Finally, in the refine step, students perform reorganizing, applying and examining their knowledge. Lim [41] defined the process of inquiry as a model of an inquiry cycle which takes account of the circular, recursive and continuous notion of inquiry. The inquiry process involves: 1) presenting an overarching question/problem or a case scenario; 2) designing students' own learning plan and problem solving strategies; 3) carrying out an investigation; 4) developing meaningful ideas and constructing new knowledge; and 5) applying their conclusion to a new situation and preparing new questions for the next cycle of inquiry.

The following four phases regarding the process of IBL are commonly described in the literature [17, 18, 41, 74].

1. **Presenting phase**: In the presenting phase, the instructor presents information and background in order not only to stimulate student interest in or curiosity about a topic, but also to help students develop a plan for their inquiry.

2. **Retrieving phase**: Students, in the retrieving phase, explore and query data and information for their inquiry, and develop skills and strategies to not only select relevant information, but also adjust and modify inquiries.

3. **Developing phase**: In the developing phase, students perform developing ideas and construct new knowledge. This phase requires students to evaluate and interpret the data and information collected in the retrieving phase.

4. **Evaluating phase**: In the evaluating phase, the developed ideas and student

inquiry process are evaluated by the instructor and other students, and constructive feedback is given enabling improvement in the future.

Throughout the entire process of IBL, students may revise their ideas or decide to go forward with the intended direction by looking back at the question, process and direction of the inquiry. Students also communicate with others to fully understand given information, and clarify or solidify their findings.

2.4.3 A Web-enabled IBL Model: WebQuest

WebQuest [72] is a WLSS for IBL and is designed according to the guidelines proposed by Dodge [14]. Well-designed WebQuests promote learning practices by integrating the idea of IBL with Internet resources, open-ended questions and authentic tasks stimulating students' motivation [8]. WebQuest is also a flexible model for Web-enabled IBL [22]. Instructors are able to very simply create their own WebQuests if they can create a document with hyperlinks [72]. Figure 2.5 illustrates an example of a WebQuest on human learning.

A WebQuest should contain at least the following six components [22]:

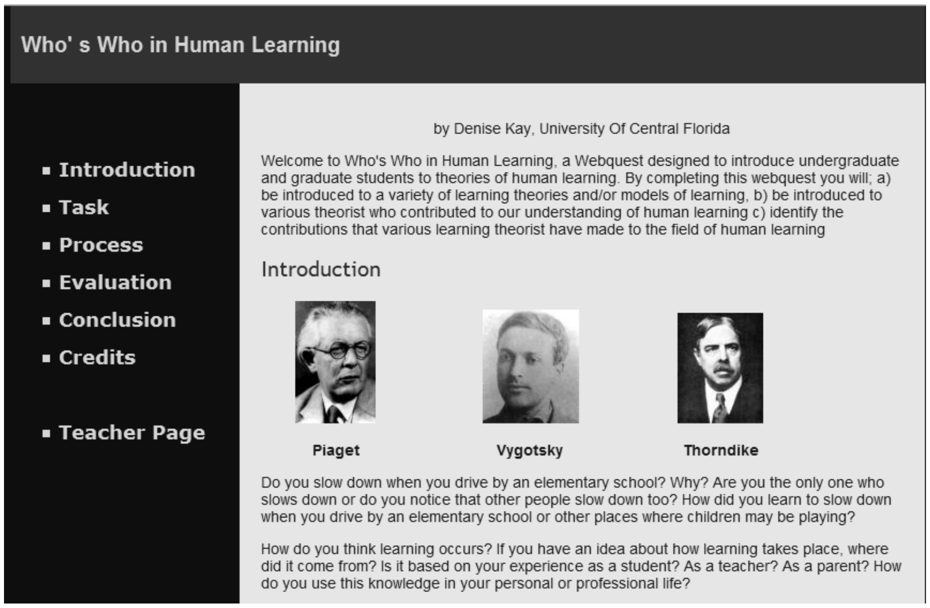
1. **Introduction**: Provides some background information allowing students to be ready to investigate a quest.

2. **Task**: Specifies an interesting and doable task, duty, or assignment.

3. **Resource**: Contains a collection of information sources - links and references - necessary to complete the task.

4. **Process**: Describes the steps students should go through in accomplishing the task.

5. **Evaluation**: Shows an assessment rubric informing how student performance will be evaluated.



by Denise Kay, University Of Central Florida

Welcome to Who's Who in Human Learning, a Webquest designed to introduce undergraduate and graduate students to theories of human learning. By completing this webquest you will; a) be introduced to a variety of learning theories and/or models of learning, b) be introduced to various theorist who contributed to our understanding of human learning c) identify the contributions that various learning theorist have made to the field of human learning

Introduction

Do you slow down when you drive by an elementary school? Why? Are you the only one who slows down or do you notice that other people slow down too? How did you learn to slow down when you drive by an elementary school or other places where children may be playing?

How do you think learning occurs? If you have an idea about how learning takes place, where did it come from? Is it based on your experience as a student? As a teacher? As a parent? How do you use this knowledge in your personal or professional life?

Figure 2.5: An Example of WebQuest.

6. **Conclusion**: Brings closure to the quest, reminds students of what they have learned, and encourages them to apply the experience to other domains.

An optional component, *credits*, shown in Figure 2.5, denotes information about permissions to use and modify the WebQuest. Another optional component, *teacher page*, guides other teachers who want to implement the WebQuest.

MacGregor and Lou [45] pointed out there is very little in the way of empirical research on the effects of WebQuests on student learning, even if many educators have voted in favour of the WebQuest model and numerous WebQuests have been created due to the flexibility and easy creation of WebQuest. They found students asked teachers for assistance more frequently than teachers expected during the WebQuest implementation in actual classrooms and the teachers felt they should design their WebQuests more carefully to provide more supportive activities and materials.

2.5 Problem Statement

Recently, Web-based learning has emerged as a promising solution to lifelong learning and is fast becoming the most popular alternative to traditional face-to-face education [2, 85]. However, Web-based learning is not always effective and sometimes fails to meet its learning objectives [75].

Some online learning systems only present text-based learning materials, which may have students feeling bored and less engaged during online learning [85]. Even the most current multimedia-based online learning systems have unstructured learning materials, which are delivered without consideration of each student's personal background and needs [21, 75, 85]. Students may passively take part in learning activities in a Web-based learning environment where one size fits all instructional design solutions will suffer because of its passive nature [75].

Moreover, in many online learning systems, instructors are not required to simultaneously participate in their students' learning process and students normally study a subject in isolation [26, 85]. This results in a lack of interaction between a student and his/her instructor [26, 34, 85]. Passive, asynchronous Web-based learning makes it difficult for students to become motivated towards learning [33, 37, 85]. The goal of this research is to design and implement a WLSS to stimulate students' motivation and encourage students to take part in their learning.

2.5.1 New Approach

Learning games encourage students and motivate toward study [58]. However, there is little empirical evidence a learning game is able to promote learning without interaction, led by instructors and instructional activities [13, 35]. Therefore, learning games might be better used as a means to support educational courses and to enlarge the instructional effect of the courses. In this sense, WLSS may well be conceptually a better framework than online learning systems in adopting the learning games. The learning games combined in WLSS may support student learning under the supervision of instructors, while online learning systems basically focus on delivering online courses.

Nevertheless, this approach faces another problem: "how to integrate learning games into WLSS in a way that maximizes learning effectiveness." Jong *et al.* [33] suggested traditional teaching approaches be combined with game-based learning in terms of the improvement of the learning effectiveness. Ke [35] reported learning games, carefully aligned with sound teaching approaches, promote good learning outcomes. Kebritchi and Hirumi [36] described games with student-centered approaches are more effective and attractive than games with basic drill-and-practice approaches.

IBL is a student-centered teaching method and is more effective than traditional teaching for achieving a variety of student learning outcomes [66]. Web-based learning environments, designed with IBL, are able to furnish students with cognitive tools and help them form a learning community in which instructors and students interact to solve complex problems [41].

According to the previous researches [33, 35, 36, 41, 66], we choose IBL as a teaching approach whereby WLSS and learning games can be combined and solve the problem. We propose and apply a treasure hunt model, which represents the idea of IBL, to the design of *OTHI*, a WLSS for IBL. We hope this system provides students with an appropriate IBL environment in which they can experience IBL and actively take part in learning. In the following chapter, we present the treasure hunt model.

Chapter 3

Definition of a Treasure Hunt Model

Chapter 3 addresses a treasure hunt for learning and defines a treasure hunt model in which the idea of IBL is incorporated. First of all, to support the definition of the treasure hunt model, learning order relationship and its knowledge spaces are presented first in this chapter.

3.1 Learning Order Relationship and Knowledge Spaces

This section defines a learning order relationship and its knowledge spaces, including a learning order relation. The definitions will be utilized in further discussion as to what learning objects the students have learned and what objects might be next in Section 3.3.2, as well as presenting how to construct knowledge in Section 3.3.3. A portion of this section have been published in a conference of *SPIE* [79].

3.1.1 Learning Order Relationship

Wong and Yao [73] defined a user preference in order to introduce an adaptive linear model for an information retrieval system. They presented a strict preference relation and an indifference relation, which is an equivalence relation regarding the preference relation called a weak order. Learning order relationship represents a user preference of a student who tries to choose and learn a more suitable learning object between two related learning objects in accordance with his/her background knowledge.

Generally, the posterior concepts of a course textbook require students to know the prior concepts of the textbook for the sake of understanding. Although some concepts are not mandatory in order to learn other concepts in a document, those concepts are required to comprehend in order to understand the document itself, which is represented by a broader concept. As long as concepts are discussed in the same document, they cannot be logically independent from others, and they can be compared with each other in order to measure the level of difficulty. In a collection of documents, if the content of any two documents are semantically related to each other, the relative difficulty of understanding or learning between the two documents is judged by students, based on their background knowledge.

Objects to be dealt with in the course of this thesis might be significant words, concepts, topics, educational materials, information units, documents, functions, commands, etc [32]. *Learning order of objects* provides the correct order in which a student is supposed to learn the other objects which remain after learning one object.

Definition 3.1 *We say that the relationship between two objects and satisfying the learning order of objects is called learning order relationship.*

In other words, the learning order relationship between two related objects can be clearly expressed as follows: *Learning one object is a prerequisite for learning another object.* It reflects the student's relative preference for the objects, based on his/her background knowledge. Figure 3.1 shows an example of the learning order of concepts in a textbook. The student may prefer "Concept 2 of chapter 3" to "Concept 3 of chapter 3" as their next learning concept.

The learning order relationship between two related objects can also determine

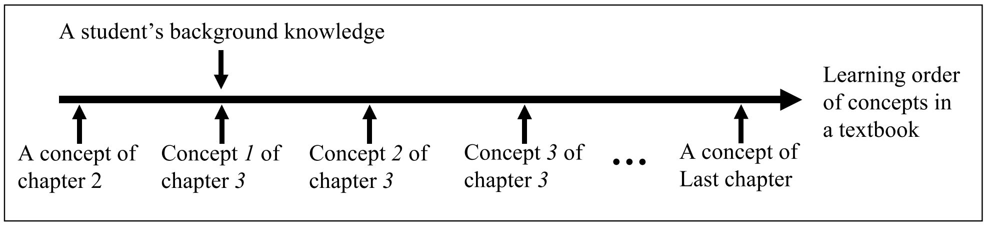

A student's background knowledge
Learning order of concepts in a textbook
A concept of chapter 2
Concept 1 of chapter 3
Concept 2 of chapter 3
Concept 3 of chapter 3
...
A concept of Last chapter

Figure 3.1: An Example of Learning Order of Concepts.

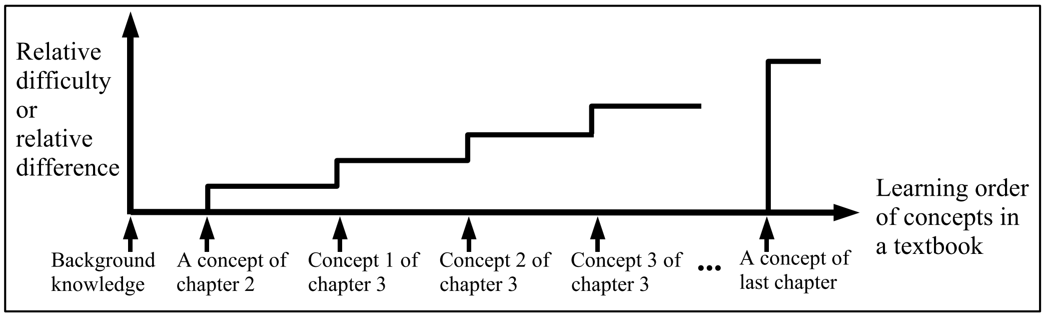


Figure 3.2: Relative difficulty or relative difference in learning order of concepts in a textbook.

which object is more difficult. Students naturally feel the posterior concepts in a course textbook are more difficult than the prior concepts, as the posterior concepts require students to have knowledge of the prior concepts first. In addition, students tend to make estimates and *educated guesses* [27] regarding a new concept in a class, and they feel relaxed if the concept is very close to their guess. As shown in Figure 3.2, the more a concept differs from the student's knowledge base, the more difficult the concept is to guess and understand. Thus, for a course, the last concept in the learning order of concepts becomes the most different and difficult concept. In the same way, the more an object is different from what a student has known, the more difficult the object becomes to guess and understand.

A concept is said to be a sub-concept or a super-concept of another concept [83]. A group of related objects can become a super-object by overlapping the objects. On the contrary, an object can be disjointed into its sub-objects.

Definition 3.2 *We say that a learning order relationship exists between any two objects in a new set which is formed by overlapping or disjointing objects in a set of related objects.*

In a course design, a teacher considers learning objects students will learn in class. The teacher may overlap or disjoint objects of the course in order to build a set of objects to teach, based on how detail each topic will be presented to students with his/her lecture allotment. Likewise, in the system, an instructor may overlap or disjoint objects of a course, since the system needs to limit the maximum number and minimum number of objects the instructor is able to define for the course due to limited system resources and effective service delivery. Even in this case, the learning order relationship is still available to represent the user preference between the objects belonging to the new set, as stated in Definition 3.2.

3.1.2 Knowledge Spaces on Learning Order Relationship

The knowledge of a student can be profiled by assessing the student's competence. From this standpoint, in a knowledge space theory, a topic can be defined by a finite set of problems, questions, or *items* the student must learn to solve [19]. Some problems may be solvable by the student only if some other problems have been previously mastered by the student [20]. Let Q be a set of *items* for a particular topic. If K is a subset of Q, K is called a *knowledge state* and the set of all possible knowledge states is called the *knowledge structure* on Q [60].

Let $\mathcal{K}$ be a knowledge structure on Q and $q \in Q$. Then $\mathcal{K}(q)$ is the collection of all knowledge states containing the item q and denoted by:

$$\mathcal{K}(q) = \{K \in \mathcal{K} | q \in K\}. \tag{3.1}$$

The intersections of all such knowledge states in $\mathcal{K}(q)$ are described by:

$$\bigcap \mathcal{K}(q) = \bigcap_{K \in \mathcal{K}(q)} K. \tag{3.2}$$

For a knowledge structure $\mathcal{K}$ on Q, the relation $R \subseteq Q \times Q$:

$$q_1 R q_2 \Leftrightarrow q_1 \in \bigcap \mathcal{K}(q_2), \forall q_1, q_2 \in Q, \tag{3.3}$$

is called a *surmise relation* on Q [4] and interpreted as meaning every knowledge state K containing q_2 should also contain q_1 [44]. The surmise relation is a quasi-order, which is reflexive and transitive. For $q_1, q_2 \in Q$, another interpretation of $q_1 R q_2$ is a student can surmise a correct response to problem q_1 from a correct response to problem q_2. It can also be said mastering item q_1 is a prerequisite for mastering item q_2 [1]. Thus, the surmise relation R on Q describes the prerequisite relationship between two items in the set Q [1, 4].

Let T be a finite nonempty set of all objects in a collection of related documents. Then, a binary relation on T, with respect to Definition 3.1, is called a *learning order relation* $\preceq$. The learning order relation $\preceq$ on T can be formally defined by: for $t_1, t_2 \in T$,

$$\begin{aligned} t_1 \preceq t_2 \Leftrightarrow \quad & \text{anyone who is able to learn } t_2 \\ & \text{should also be able to learn } t_1. \end{aligned} \tag{3.4}$$

t_1 is called a *prior* object of t_2, and t_2 is called a *posterior* object of t_1. The prior object t_1 of t_2 can be regarded as a prerequisite for mastering t_2. The learning order relation $\preceq$ on T also describes the prerequisite relationship between two objects in the set T.

A subset of T can be the knowledge state, and a knowledge structure on T can be restricted by the *learning order relationships* between objects in T. Thus, for a learning order relation $\preceq$ on T, a knowledge structure, associated with the relation, is defined by:

$$\mathcal{K}_R = \{K | (\forall t, t^{'} \in T, t^{'} \preceq t, t \in K) \Rightarrow t^{'} \in K\}. \tag{3.5}$$

It means a knowledge state $K \in \mathcal{K}_R$ contains all the prerequisites of an object t if t is an element of K, and the prerequisites are linearly ordered along with one single dimension, taking the learning order relation as deterministic. Hence, the object t can only have one set of prerequisites. The knowledge structure $\mathcal{K}_R$ contains the empty set $\emptyset$ and the entire set T, and is closed under set union and intersection.

Definition 3.3 *We say that a learning order relation $\preceq$ of the knowledge structure $\mathcal{K}_R$ on T is a quasi-order relation on T satisfying the following axioms:*

$$\begin{aligned}&(1) \text{ if for} \forall t \in T, t \preceq t \text{ holds,}\\&(2) \text{ if for} \forall (t, t^{'}, t^{''}) \in T^3, (t \preceq t^{'}) \text{ and } (t^{'} \preceq t^{''}), \text{ then } (t \preceq t^{''}).\end{aligned}$$

As previously described, in the knowledge structure $\mathcal{K}_R$, an object can have only one set of prerequisites, which is able to provide one *learning path* to the student. However, in practice, it is possible for an object to have more than one set of prerequisites. A mapping $\sigma : T \rightarrow 2^{2^T}$ is called a *surmise function* [60] if it satisfies the following conditions: 1) $P \in \sigma(t) \Rightarrow t \in P$; 2) $(P \in \sigma(t), t^{'} \in P) \Rightarrow (\exists P^{'} \in \sigma(t^{'}), P^{'} \subseteq P)$; and 3) $P \in \sigma(t) \Rightarrow (\forall P^{'} \in \sigma(t), P^{'} \nsubseteq P)$. The interpretation of a surmise function $\sigma(t) = \{P_1, \cdots, P_n\}$ is that every student who is able to learn an object t is also able to learn all objects from at least one element P_i of $\sigma(t)$. The elements in $\sigma(t)$ are presented as sets of prerequisites for an object t.

The pair (T, σ) represents a *surmise system* [76]. For the surmise system, a knowledge structure $\mathcal{K}_S$ on T, in which an object t can have sets of its prerequisites $\sigma(t)$, is described as:

$$\mathcal{K}_S = \{K | (\forall t \in T, t \in K) \Rightarrow (\exists P \in \sigma(t), P \subseteq K)\}. \tag{3.6}$$

The knowledge structure $\mathcal{K}_S$ associated with the surmise system (T, σ) is called a *knowledge space* on T, which is closed under union. The knowledge space can represent a collection of all possible *learning paths*, for all objects in T, with respect to the learning order relationship. We hereafter use $\mathcal{K}_S$ to denote the knowledge space unless explicitly stated otherwise.

Let T_K^O be the outer fringe [1] of $K \in \mathcal{K}_S$. $T_K^O \subset T$ is a set of all objects t such that adding t to K forms another knowledge state $K^{'} \in \mathcal{K}_S$. Let $T_K^I \subset T$ be the inner fringe [1] of K. T_K^I is a set of all objects t such that removing t from K forms another knowledge state $K^{''} \in \mathcal{K}_S$. Thus, objects in the outer fringe T_K^O are the *next objects* to be suggested to the student whose current knowledge state is K.

Example 3.1 *Suppose a learning order relation* $\preceq$ *on* $T = \{t_1, t_2, t_3, t_4, t_5, t_6, t_7\}$ *is specified by:*

$$t_1 \preceq t_2,\ t_1 \preceq t_3,\ t_1 \preceq t_4,\ t_2 \preceq t_5,\ t_3 \preceq t_5,\ t_4 \preceq t_6,\ t_5 \preceq t_7,\ t_6 \preceq t_7.$$

The learning order relation $\preceq$ on T implies the following relationships:

$$\begin{gathered} t_1 \preceq t_1,\ t_2 \preceq t_2,\ t_3 \preceq t_3,\ t_4 \preceq t_4,\ t_5 \preceq t_5,\ t_6 \preceq t_6,\ t_7 \preceq t_7, \\ t_1 \preceq t_2,\ t_1 \preceq t_3,\ t_1 \preceq t_4,\ t_1 \preceq t_5,\ t_1 \preceq t_6,\ t_1 \preceq t_7,\ t_2 \preceq t_5, \\ t_2 \preceq t_7,\ t_3 \preceq t_5,\ t_3 \preceq t_7,\ t_5 \preceq t_7,\ t_4 \preceq t_6,\ t_4 \preceq t_7,\ t_6 \preceq t_7. \end{gathered}$$

From Equation (3.5), a knowledge structure $\mathcal{K}_R$ on T is obtained:

$$\mathcal{K}_R = \{\emptyset, \{t_1\}, \{t_1, t_2\}, \{t_1, t_3\}, \{t_1, t_4\}, \{t_1, t_4, t_6\}, \{t_1, t_2, t_3, t_5\}, T\ \}.$$

It shows every object has only one set of prerequisites, providing one *learning path.* For example, to learn t_6 a student should learn t_1 and t_4, and there are no other paths available to reach t_6. More *learning paths* to the object t_6 can be found with a surmise function $\sigma(t_6) = \{\{t_1, t_4, t_6\}, \{t_1, t_2, t_4, t_6\}, \{t_1, t_3, t_4, t_6\}, \{t_1, t_2, t_3, t_4, t_6\}, \{t_1, t_2, t_3, t_4, t_5, t_6\}\}$. We can form a knowledge space $\mathcal{K}_S$ on T as follows:

$$\begin{aligned}\mathcal{K}_S = \{\ &\emptyset, \{t_1\}, \{t_1, t_2\}, \{t_1, t_3\}, \{t_1, t_4\}, \{t_1, t_2, t_3\}, \{t_1, t_2, t_4\}, \{t_1, t_3, t_4\},\\ &\{t_1, t_4, t_6\}, \{t_1, t_2, t_3, t_4\}, \{t_1, t_2, t_3, t_5\}, \{t_1, t_2, t_4, t_6\}, \{t_1, t_3, t_4, t_6\},\\ &\{t_1, t_2, t_3, t_4, t_5\}, \{t_1, t_2, t_3, t_4, t_6\}, \{t_1, t_2, t_3, t_4, t_5, t_6\}, T\ \}.\end{aligned}$$

For a knowledge state $K = \{t_1, t_2, t_3\}$ in $\mathcal{K}_S$, the outer fringe of K and the inner fringe of K are the sets $T_K^O = \{t_4, t_5\}$ and $T_K^I = \{t_2, t_3\}$, respectively. Therefore, a student may choose one of two objects, t_4 and t_5, as the next object to learn if the student has learned objects t_1, t_2 and t_3.

3.2 Treasure Hunts and Inquiry-Based Learning

In this section, an overview of current treasure hunts for learning and a treasure hunt process for IBL are presented in order to disclose the fundamental idea of our approach to the problem.

3.2.1 Treasure Hunts for Learning

Treasure hunt was originally an outdoor activity and a game played by children and occasionally by adults. To play treasure hunt, an adult prepares a list of hidden objects for children to find. Each team of children receives a duplicate list of the hidden objects. The winner is the first team to find all the items on the list.

Mechling [49] laid out a treasure hunt game played by a Boy Scout troop. The game requires game organizers to spend a few days preparing the hunt as follows: 1) deciding game boundaries, the location for hiding the treasure and the location of the stations along the route from the camp to the treasure site; 2) creating a chain of clues that lead the game teams from one station to another; and 3) allocating the tasks and necessary equipment to the stations. He also described the important elements of a modern treasure hunt: rhymed clues, riddles, clues written in code, performances at stations of the hunt, and foodstuffs as treasures. During the treasure hunt, the scouts are requested to follow all the rules and use their physical skills and strategies to overcome given challenges.

Dr. Clue (`http://www.drclue.com`), a corporate team-building company specializing in business-focused treasure hunts, presented a reinvented treasure hunt model in which groups work together to solve a series of tricky riddles and clues, leading to mystery locations where answers appear. Blas *et al.* [3] introduced an online treasure hunt game in the SEE project providing students with a virtual learning environment. Students are included in online meetings and discuss previously studied themes under the active supervision of a guide, in a virtual museum. A treasure hunt in the SEE project helps students find a solution to cultural riddles provided by the museum, and enables them to review their learning in exciting ways. Hamelin [27] described an IBL experiment, in the form of a treasure hunt on the Web. It has been shown a treasure hunt can be a very effective tool in developing searching abilities, using the Internet [27].

3.2.2 A Treasure Hunt Process for Inquiry-Based Learning

A treasure hunt can be well matched to IBL. *Treasure* is considered to be information, truth, or knowledge, and *hunt* implies inquiry, which is a systematic investigation. *Treasure hunt* is an inquiry activity in which one systematically seeks knowledge with questions.

Figure 3.3 shows the process of the treasure hunt which we exploit in order to

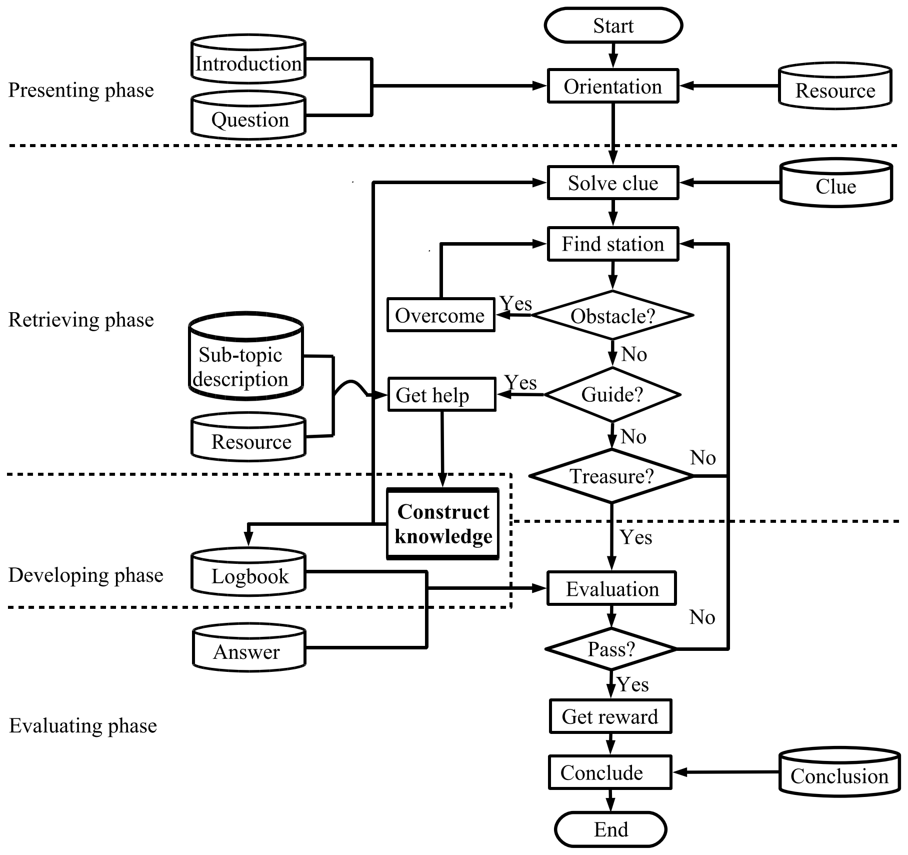


Figure 3.3: Flowchart of a treasure hunt process.

design a WLSS for IBL. The process has the following four phases:

1. **Presenting Phase**: In an orientation, a guide provides students with a question regarding a topic which they will investigate via a treasure hunt, as well as the outlines of the topic. The background information is available from a *resource* and helps students easily understand the objectives of the topic and the question.

2. **Retrieving Phase**: Once students receive their orientation from the presenting phase, they are required to explore every necessary *station* using the given *clues* and meet guides who offer a related sub-topic description called *help*. Students need to understand the sub-topic, using its *resource*, so as to construct

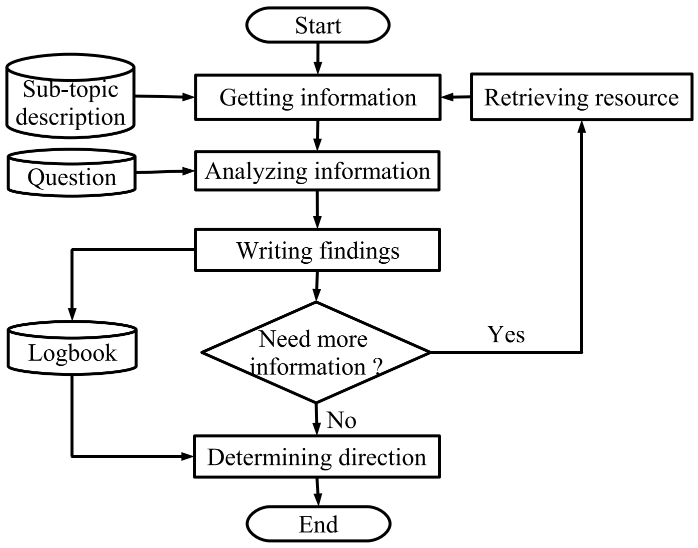


Figure 3.4: Flowchart of a knowledge construction.

a correct answer to the question. While exploring stations, students may meet and overcome several *obstacles*, and find *treasures*.

3. **Developing Phase**: When students obtain *help* at a *station*, they may develop ideas for the answer to the question through the "Construct knowledge" process, shown in Figure 3.3. A more detailed flowchart is depicted in Figure 3.4. Students analyze their collected information, and write an idea, from their analysis, into their *logbook*. If they require more information to understand the given information, they may search a *resource*. By reviewing the ideas in the logbook, the students determine where to find more *helps* with the question, and thereby construct a correct answer to the question.

4. **Evaluating Phase**: Students are required to take a test when they find a treasure at a *station*. In the evaluation, students must answer the question they received in the presenting phase, referring to ideas in their *logbook*. The answer is compared with the sample answer (prepared by the instructor) to determine whether they pass the test. If the students pass, they receive points and a

reward which is useful in overcoming *obstacles* they will meet in future rounds, and they are also able to know available topics for the next round of treasure hunt. The winner is the student or team with the greatest number of points.

Each phase has its corresponding phase in the IBL process described in Section 2.4.2. The IBL process is also observed in this process. Therefore, it can be said treasure hunt does include the idea of IBL.

3.3 A Treasure Hunt Model for Inquiry-Based Learning

Before designing a WLSS, featuring treasure hunt, it is necessary to clearly define a treasure hunt by creating a *treasure hunt model.* In so doing, we come to understand what components and functions are needed, and how the functions might work for the system conducting the *treasure hunt* for IBL. The treasure hunt model is thoroughly discussed in this section.

3.3.1 Structure of a Treasure Hunt Model

The treasure hunt model formalizes the treasure hunt, discussed in Section 3.2.2, using set theory in order to efficiently integrate the learning strategies of IBL into WLSS. It also provides an efficient way to combine the Web and online game technologies in the designing of WLSS for IBL.

The treasure hunt model consists of seven components: *agents*, *treasures*, *information*, *events*, *actions*, *stations*, and *logbooks.* Its structure is defined as follows:

$$S = (AGT, TRE, INF, EVT, ACT, STA, LOG). \tag{3.7}$$

- AGT is a finite nonempty set of *agents* representing students or guides in the system, and expressed as $AGT = SD \cup GI$, where SD is the set of all students and GI is the set of all guides. Guides help students find treasures by providing useful information about the treasures.

- TRE is a finite nonempty set of *treasures*. A *treasure* is the conclusion of a topic and a reward for learning the topic. The *reward* is useful in helping students overcome obstacles to find other treasures.

- INF is a finite nonempty set of *information* about the treasures. This is defined as $INF = \{TP, RS, QS, CL\}$, where TP is a finite nonempty set of learning topics, RS is a finite nonempty set of resources, QS is a finite nonempty set of questions, and CL is a family of nonempty sets of clues. A *learning topic* is a finite nonempty set of learning *objects* necessary to master a topic. The *resource* is a collection of information sources related to a learning object. The *question* is what students must investigate while learning a topic. The *clue* is a rhymed hint about the next learning object to be found and learned.

- EVT is a finite nonempty set of *events* which invite student participation. There are four different types of events: orientation events, help events, obstacle events and evaluation events.

- ACT is a finite nonempty set of *actions* students can perform in order to find the *treasure*. Some major actions are as follows: finding the information, analyzing the information, retrieving the resource, documenting the findings and determining the direction.

- STA is a finite nonempty set of *stations* where the event occurs and students initiate the actions. In accordance with the events, the stations can be grouped into the following types: orientation stations, help stations, obstacle stations and evaluation stations.

- *LOG* is a finite nonempty set of *logbooks* containing all records of the students' important achievements during the treasure hunt. Students record their findings in the logbooks, the contents of which assist them in constructing new knowledge.

Let n be the number of topics for a course and let m be the number of sub-topics of each topic. TP of INF in Equation (3.7) can be expressed as $TP = \{L_1, L_2, \cdots, L_n\}$, where L_i (for $1 \leq i \leq n$) is the learning topic. Learning topic L is described as $L = \{k_0, k_1, k_2, \cdots, k_m, k_{m+1}\}$, where k_0 is the *introduction* of the topic, k_i (for $1 \leq i \leq m$) is a *sub-topic* of the topic, and k_{m+1} is the *conclusion* of the topic. In the treasure hunt model, a set T of all learning objects, which students are required to understand in order to complete *a course* through the treasure hunt, is defined as:

$$T = \bigcup_{L \in TP} L. \tag{3.8}$$

Let $IT \subset T$ be a set of all the *introductions* of topics for a course, let $SU \subset T$ be a set of all the *sub-topics*, and let $CO \subset T$ be a set of all the *conclusions* of topics. Thus, the set T of all the objects of the course is also defined as:

$$T = IT \cup SU \cup CO. \tag{3.9}$$

The learning objects are allocated to stations and guides using a learning object allocation function f_{OA} given by:

$$f_{OA} : T \rightarrow STA \times GI. \tag{3.10}$$

If TN is a finite nonempty set of names of topics for a course, an orientation function

f_{OT} representing the orientation event of EVT in Equation (3.7) is described as:

$$f_{OT} : STA \times GI \times TN \rightarrow IT \times QS \times CL. \tag{3.11}$$

The orientation function f_{OT} allows a guide to provide an introduction, a question and a clue for a given topic name at a station. The introduction is called an *orientation object*. A help function f_{HL} for the help event of EVT is expressed as:

$$f_{HL} : STA \times GI \times QS \rightarrow SU \times CL. \tag{3.12}$$

The definition of the help function f_{HL} describes a guide furnishing a sub-topic description and a clue for a given question at a station. The sub-topic description is called a *help object*.

Let $f_{SM}(q, t, t^{'})$ be a similarity function to measure the similarity of a student answer $t^{'}$ to a sample answer t, provided by the instructor, for a given question $q \in QS$. If S_q is a set of significant terms appearing in the question q, S_t is a set of significant terms appearing in the sample answer t, and $S_{t'}$ is a set of significant terms appearing in the student answer $t^{'}$, then the similarity can be calculated by:

$$f_{SM}(q, t, t^{'}) = \frac{|S_{t'} \cap (S_q \cup S_t)|}{|S_q \cup S_t|}. \tag{3.13}$$

It means the similarity is measured by the ratio between the number of significant terms, included in both the student answer and the sample answer or question, and the number of significant terms, included in the sample answer or question.

If RW is a set of rewards the student receives after passing a test at an evaluation event, the set of treasures TRE in Equation (3.7) can be described by $TRE = CO \times RW$, where CO is a set of all the topic *conclusions* as previously described.

Therefore, an evaluation function f_{EV} for the evaluation event of EVT is defined as:

$$f_{EV} : STA \times QS \times R(f_{SM}) \to TRE, \tag{3.14}$$

where $R(f_{SM})$ is the range of f_{SM}. The evaluation function f_{EV} expresses the fact a student is able to obtain a reward and a conclusion of the topic as a treasure, at a particular station, based on the similarity of their answer to a sample answer for a question. The conclusion is called an *evaluation object*.

The obstacle event gives students enjoyment, and hinders their ability to find the treasures. If OB is the finite nonempty set of obstacles, an obstacle function f_{OB} for the obstacle event of EVT is described as:

$$f_{OB} : STA \times OB \times 2^{RW} \to \mathbb{N}, \tag{3.15}$$

which represents how well students overcome an obstacle at a station using rewards, which they obtained. Students acquire some points while struggling with the obstacle at a station, using the rewards they received.

3.3.2 Learning State of the Treasure Hunt Model

The system needs to know students' current learning states in order to arrange the next objects the students are to learn, based on each student's learning state. It is very clear the treasure hunt model should define the learning states and explain how to derive the next objects.

In Section 3.1.2, we discussed a way to discover the next objects from the current knowledge state of the student, using the learning order relationship. Now, the concept of the knowledge space, defined by Equation (3.6), allows us to discuss the learning state, which shows a student's learning progress. Furthermore, we are able to present how the current knowledge state of a student is changed by student's learning experience.

If LS is a learning state structure, LS can be defined as a tuple:

$$LS = (SD, t_0, \lambda, LE, f_{LE}), \tag{3.16}$$

where SD is a finite set of students, t_0 is a course introduction, λ is the sequence of stations, LE is the set of learning experiences a student has in order to complete a course, and f_{LE} is an experience interpretation function.

Let $\mathcal{K}_S$ be a knowledge space on T, defined in Equation (3.8), and λ be the sequence of stations a student visits in the treasure hunt. *Learning*, in the treasure hunt model, takes place at a station $s_\lambda \in STA$ as a student takes a series of actions A_λ based on the student's current knowledge state $K_\lambda \in \mathcal{K}_S$, for a given object $t_\lambda \in T^O_{K_\lambda}$, the outer fringe of K_λ. The series of actions A_λ is expressed as $A_\lambda = (a_1, \cdots, a_l)$, where l is the number of actions which the student takes at the station, and for $1 \leq i \leq l$, $a_i \in ACT$ from Equation (3.7).

The set LE of learning experiences can be expressed as:

$$LE = \bigcup_\lambda (s_\lambda \times K_\lambda \times t_\lambda \times A_\lambda). \tag{3.17}$$

If there is a function $f(\lambda) : \mathbb{N} \to LE$, the experience interpretation function f_{LE} is defined as:

$$f_{LE} : t_0 \times \prod_\lambda f(\lambda) \to K_n, \tag{3.18}$$

where t_0 is the course introduction and $K_n \in \mathcal{K}_S$ is the new knowledge state of the student. K_n will be used as the current knowledge state in the next station, replacing the old knowledge state of the student. As described in Section 3.1.2, for the new knowledge state K_n, the next available objects for the student can be denoted by

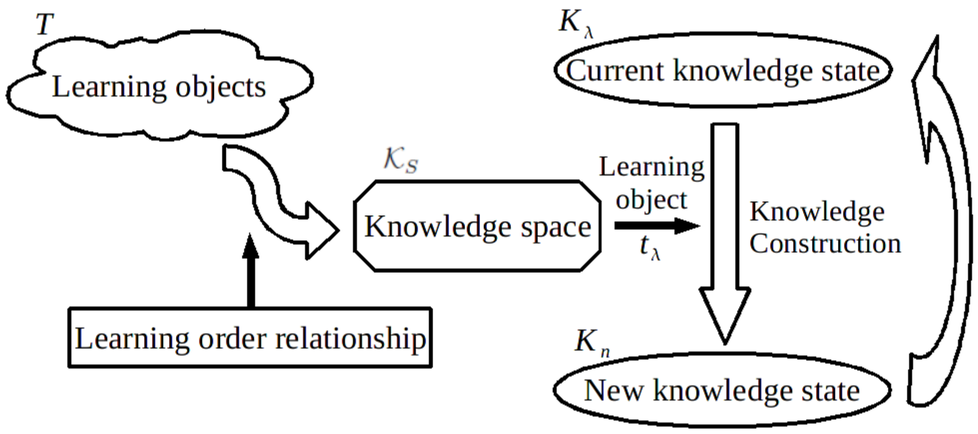


Figure 3.5: High-level view of the treasure hunt model.

$T^O_{K_n}$, the outer fringe of K_n.

According to the learning state structure, the past learning states of a student are retrieved by changing the sequence λ. LE in the structure may be a data storage, wherein the learning experiences of a student are kept. The system writes the learning experiences into the data storage. The past learning experiences can be the learning history of the student. The learning history is also retrieved from LE by changing the sequence λ.

3.3.3 Knowledge Construction of the Treasure Hunt Model

It is important that the treasure hunt model defines the process of the *knowledge construction*, depicted in Figure 3.4. Figure 3.5 shows a high-level view of the treasure hunt model, including the knowledge construction. Learning objects in T make up a knowledge space $\mathcal{K}_S$ by applying learning order relationships between the objects. The student chooses a learning object t_λ among the available objects derived from the knowledge space $\mathcal{K}_S$, based on his/her current knowledge state K_λ.

In fact, for Equation (3.17), all the essential *actions* for learning are involved in the knowledge construction process. The first information, given to the student at the station $s_\lambda \in STA$, is the object t_λ the student chose for this round of treasure hunt. The student is able to construct knowledge by writing an idea, from the analysis of given information, into the logbook, and attain a new knowledge state $K_n \in \mathcal{K}_S$. The student may retrieve the *resource* related to the object t_λ to obtain more information and clearly understand it. The current knowledge state K_λ is replaced with the new knowledge state K_n for the next round.

In the system, the *blog* works as the logbook. If IS is an idea structure describing the idea posted to the *blog*, IS can be defined as a tuple:

$$IS = (QS, \lambda, SBJ, CMT, REL), \tag{3.19}$$

where QS is a finite nonempty set of questions from INF of Equation (3.7), λ is the sequence of stations, SBJ is a set of subjects, CMT is a set of comments, and REL is a set of relationships. The *subject* is the title of the *comment*, and the *relationship* represents the relationship between the *question* and the *comment*. A *writing idea* function f_{WI}, posting an idea to the *blog*, is defined as:

$$f_{WI} : QS \times \mathcal{K}_S \times T \times RS \to IS, \tag{3.20}$$

where T is the set of all the objects as defined in Equation (3.8), $\mathcal{K}_S$ is the knowledge space on T, and RS is a finite set of resources from INF of Equation (3.7). The function f_{WI} is a mapping function specifying an idea developed from the given learning object and related resource, based on the current knowledge state of the student in order to find a correct answer to a question.

The idea structure IS presents fields which may compose a blog entry form. The function f_{WI} also describes the information available from the system, allowing the student to fill out the fields on the entry form.

3.4 Summary

This chapter presents several different types of treasure hunts for learning, including a Boy Scout troop's treasure hunt, a team-building treasure hunt, a treasure hunt in an online-learning game, and a treasure hunt using the Web. The chapter also specifies the process of a treasure hunt which implies the idea of IBL, and formalizes the treasure hunt into a treasure hunt model using set theory.

The treasure hunt model, which is a new Web-enabled IBL model, is made up of the following components: agents, treasures, information, events, actions, stations, and logbooks. *Agents* are live objects in the system; *treasures* represent topics students need to master; *information* is the content of the learning objects of the topics, as well as questions and clues necessary to obtain the *treasures*; *events* take place to provide students with the *information* and obstacles, and evaluate their treasure hunt; *actions* are the actions students can take according to the *events*; *stations* are the places where the *events* occur; and *logbooks* have the acquired *information* and ideas developed by students during their journeys to the *treasures*. The treasure hunt model furnishes the following functions: a learning object allocation function, an orientation function, a help function, a similarity function, an evaluation function, an obstacle function, an experience interpretation function, and a writing idea function.

To facilitate the definition of the treasure hunt model, we proposed a learning order relationship and its knowledge spaces at the beginning of this chapter. The learning order relationship represents a student's preference to two related learning objects, and enables the student to specify the learning order of objects in a correct manner, based on his/her preconceived notions and existing personal knowledge. We also define a learning order relation, which is a binary relation on the objects with respect to the learning order relationship.

The knowledge space theory is involved to further investigate the properties of the learning order relationship in this chapter. The knowledge structure and knowledge space of the learning order relationship are defined. Through these definitions, the chapter presents a surmise relation, a quasi-order relation, a surmise function and a surmise system regarding the learning order relationship. Furthermore, the chapter derives sets of prerequisites of an object from the knowledge space, and describes the outer fringe and inner fringe of the current knowledge state of the student.

Finally, the chapter addresses the learning state, learning experience and knowledge construction process of the treasure hunt model. The learning state shows the student's learning progress including the learning experiences of the student. The knowledge construction process is expressed with both the idea structure which represents the idea posted to the *blog*, and the writing idea function which describes posting an idea to the *blog*. The following chapter presents the implementation and demonstration of a WLSS, complying with the treasure hunt model.

Chapter 4

Implementation and Demonstration

Chapter 4 details several algorithms for two major functions of *OTHI*, describes the implementation of its prototype, presents the demonstration of the prototype system with a topic from a data communications and network course, and discusses the usefulness of *OTHI*. *OTHI* is a WLSS for IBL and is designed on the basis of the treasure hunt model. The system employs an online treasure hunt game to allow students to experience IBL while playing the game.

4.1 Overall System Architecture

The architecture of *OTHI* is depicted in Figure 4.1. It basically follows the thin-client and server structure and three-layer architecture presented in Section 2.2.2. *OTHI* has the following major subsystems: (1) a treasure hunt game, (2) a teaching support subsystem, (3) a learning support subsystem, and (4) a membership management subsystem. The teaching support subsystem implements the teacher's view of WLSS, while the learning support subsystem implements the student's view of WLSS as described in Section 2.2.1.

The membership management subsystem manages various members such as the

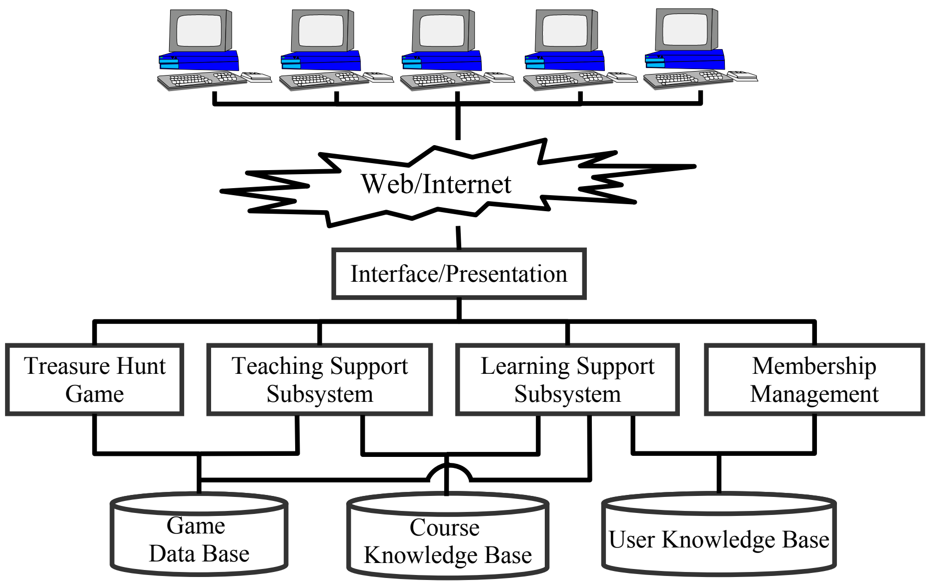


Figure 4.1: An Architecture of OTHI.

present, past and affiliate members, and supports three different types of user accounts: students, instructors and administrators. The members' profiles are managed on the user knowledge base. One of its most important features is the identification and authentication of each user. The user is able to access available services based on the authentication.

The teaching support subsystem enables instructors to design their courses as IBL. Instructors define course outlines, topics, questions, clues and related information using this subsystem. The system stores the information into the course knowledge base and generates IBL environments into the treasure hunt game. From this generation, treasure boxes containing questions, conclusions and rewards are placed at certain stations. The generation also allows non-player characters to have their own words to guide students as the *guides* of the treasure hunt model.

The learning support subsystem provides students with *resources* related to each topic as well as information about the treasure hunt. Students can search for more information about a topic using a Web search engine, if necessary. In addition, they are able to post their findings onto the *blog*, the data of which are stored in the user knowledge base. The system also automatically posts their achievements during the treasure hunt to the *blog*. The *blog* helps students develop their ideas and compose an answer to a question by tracing their findings.

Treasure hunt game provides a playground for the treasure hunt. All required information for the treasure hunt game is located in the game database. Students become motivated, and experience both the treasure hunt and IBL by playing the game. The learning support subsystem provides students with a virtual place, such as their home, where students complete homework and prepare for their next classes, while the treasure hunt game provides a different virtual place, such as a classroom where students learn from a teacher.

4.2 Algorithms

As the system is implemented based on the treasure hunt model, the system should provide two major functions as follows: (1) building a learning environment and (2) treasure hunting. Using the functions, an instructor is able to build a learning environment in which students are able to experience IBL through a treasure hunt. This section describes the two functions with algorithms: a learning environment building algorithm and a treasure hunting algorithm. Appendix B contains the algorithms.

4.2.1 Learning Environment Building Algorithm

The learning environment building algorithm presented in Algorithm 5 is an extension of both Algorithm 2 and Algorithm 4. Algorithm 2 and Algorithm 4 depict how a knowledge space $\mathcal{K}_S$ and outer fringes of knowledge states in $\mathcal{K}_S$, described in Section 3.1.2, are constructed for a course. A set T of all objects of the course is already defined by the instructor, as described in Algorithm 7, and used as a data set of Algorithm 2. In Algorithm 2, line **1** initializes the knowledge space $\mathcal{K}_S$, a knowledge state K, a set of next possible learning objects T_N and an learning object $\vec{t}$. $\mathcal{K}_S$ contains the empty set $\emptyset$ at line **2**. Line **3** creates a new knowledge state and assigns it to K by invoking the function Create_new_knowledge_state() with two parameters: a knowledge state K and an learning object $\vec{t}$. Line **5** allows the instructor to specify the next possible learning objects for students who have mastered $\vec{t}$, and adds the objects to T_N. Line **6** gets an outer fringe T_K^O of K from T_N. Line **7** invokes the recursive procedure Building_knowledge_space_and_outerfringe() to get the rest of the knowledge states of $\mathcal{K}_S$ and their outer fringes.

Algorithm 4 shows how the procedure Building_knowledge_space_and_outerfringe() works to complete building the knowledge space $\mathcal{K}_S$ and get the outer fringes. The procedure has three parameters: a knowledge space $\mathcal{K}_S$, a knowledge state K and its outer fringe T_K^O. Lines **2-8** repeat until all objects in T_K^O are processed. Line **2** invokes the function Create_new_knowledge_state() to create a new knowledge state. Line **3** adds the new knowledge state K to $\mathcal{K}_S$ if K is not an element of $\mathcal{K}_S$. Lines **5-7** are identical to lines **5-7** in Algorithm 2, and performed if K does not have all the elements of T.

Algorithm 5 is the learning environment building algorithm, which is quite similar to Algorithm 2, except that it has one more data set to use and invokes the procedure Building_learning_environment() with an additional parameter, *question*. A set STA of all stations the system provides is added as the data of the algorithm. It means

STA is already defined by the administrator of the system and each station in STA has some information about guides and treasure boxes which are placed at the station, as shown in Appendix C.1. Line **7** initializes *question*. Line **8** invokes the procedure Building_learning_environment() to actually generate components necessary to depict a treasure hunt for IBL in the treasure hunting algorithm.

The procedure Building_learning_environment() called in Algorithm 5 is shown in Algorithm 6. The procedure is also similar to Algorithm 4, except that it separately deals with each learning object according to the object's *type*: an orientation object, a help object and an evaluation object, and invokes itself instead of the procedure Building_knowledge_space_and _outerfringe(). The procedure also includes the learning object allocation function defined in Equation (3.10).

In the procedure Building_learning_environment(), lines **2-33** repeat until all objects in T_K^O are processed. Lines **3-8** are computed if the object $\vec{t}$ is an orientation object. Lines **3-5** find a station $\vec{s}$ which should have at least one guide available to keep some information. Lines **6-8** enable a guide to keep orientation information. Once the guide has the information, the guide is no longer available to keep other information. Lines **11-15** are processed if the object $\vec{t}$ is a sub-topic object. Lines **11-13** are identical to lines **3-5**. Lines **14-15** get a guide from the station and give the guide the sub-topic information. Lines **18-25** are performed if the object $\vec{t}$ is an evaluation object. Lines **18-20** find a station $\vec{s}$ which should have at least one treasure box available to keep a treasure. Line **21** gets an available treasure box $\vec{b}$ from the station. Lines **22-25** put evaluation information into the treasure box $\vec{b}$.

According to Equation (3.8), for a learning topic L, the first object to learn is about the introduction of L and the last object to learn is about the conclusion of L. To master the topic L, the student who had the orientation ends up taking the evaluation.

Definition 4.1 *We say that there must be an evaluation object, corresponding to an* *orientation object, as a posterior object of the orientation object in the learning order of objects.*

Line **32** recursively calls the procedure itself, and the parameter *question* will be used for an evaluation object, which must be a posterior object of the orientation object $\vec{t}$ in accordance with Definition 4.1.

4.2.2 Treasure Hunting Algorithm

The learning environment building algorithm describes a major function of the teaching support subsystem, while the treasure hunting algorithm describes a major function of the treasure hunt game. Algorithm 8 is the treasure hunting algorithm, whose input data contain outer fringes of all knowledge states $\in \mathcal{K}_S$ and a set STA of all stations in the system. Guides and treasure boxes, placed at the stations, already have the information and rewards to be delivered to students, according to the learning environment building algorithm.

Line **1** initializes variables. n counts how many topics are mastered; *clue* contains a clue; $\vec{t}$ is an object; $\vec{s}$ is a station; *points* are experience points; RW represents a reward inventory the student possesses; and K is a knowledge state. Line **2** introduces the course to the student. Line **3** adds the course introduction object to the current knowledge state K, and gets an outer fringe T_K^O of K. Lines **5-33** repeat until the student learns all topics of the course. Line **5** allows the student to choose one object $\vec{t} \in T_K^O$, which contains all the objects available to learn for the next round of treasure hunt. Line **6** invokes the function Explore_stations_and_overcome_obstacles() to find an appropriate station for the object $\vec{t}$. As presented in Algorithm 10, the function shows the student overcomes obstacles and gets some experience points while exploring stations.

Lines **8-13** are performed if the object $\vec{t}$ is an orientation object. Otherwise, if the object $\vec{t}$ is a help object, lines **16-22** are processed. If the object $\vec{t}$ is an evaluation object, lines **25-32** are executed. As defined in Equation (3.16), Equation (3.17) and Equation (3.18), line **8** calls the function Orientation() to give the student an orientation about a topic, line **16** invokes the function Help() to provide the sub-topic information, and line **26** invokes the function Evaluation() for the student to take a test if a treasure is found in a treasure box at the station $\vec{s}$. Lines **10-12** are processed if the orientation was provided. Line **10** adds the object $\vec{t}$ to the current knowledge state K, and get an outer fringe T_K^O of K. Line **11** displays a list of possible objects to learn and enables the student to choose an object $\vec{t}$ for the next round. Line **12** calls the function Get_clue_for_next_station() to have a clue, leading to the station where the next object $\vec{t}$ will be treated.

Lines **18-21** are processed if the sub-topic information was provided. Line **18** invokes the function Knowledge_construction() to construct an idea using the sub-topic information and get a new knowledge state K as described in Algorithm 15. Line **19** gets an outer fringe T_K^O of K. Line **20** is identical to lines **11**, and line **21** is quite similar to line **12**. Lines **28-30** are performed if the reward is available. Line **28** adds the reward to the reward inventory RW. Line **29** is identical to line **10**. Line **30** initializes variables and increases n by 1.

According to Equation (3.8), for a learning topic L, the last learning object is the evaluation object of L. It means a new topic will be introduced to the student at the next time, and the next object must be the orientation object of the new topic.

Definition 4.2 *We say that every element of the outer fringe of an evaluation object should be an orientation object in the learning order of objects.*

Line **30** shows the evaluation event does not provide any clue and the orientation information $\vec{o}$ about the current topic is no longer necessary, since a new topic will be treated for the next round according to Definition 4.2.

Table 4.1: Open source softwares used to develop the system.

Name	Version	Description	URL
Blojsom	3.2	Java-based multi-blog system	`http://wiki.blojsom.com`
Joomla	1.5.12	Content management system	`http://www.joomla.org`
Project Darkstar	0.9.10	Online game server	`http://www.projectdarkstar.com`
Slick	0.7.2	Java library for 2D game	`http://slick.cokeandcode.com`
Stendhal	0.69	Multiplayer online adventures game	`http://arianne.sourceforge.net/ ?arianne_url=games/game_stendhal`

4.3 Development Environment and Available Technologies

Developing a website including an online game usually requires many system resources, financial resources and manpower. Although this is a prototype system, it is too heavy of a workload for only one software developer if (s)he develops the whole system on their own. Therefore, it is imperative to exploit open source softwares and servers available for free. A Java-based development environment has a greater chance of finding applicable open source softwares and freely-available systems than C# and DotNet-based development environments. Hence, Java is the primary language of choice. In this section, all the software packages and core technologies, used in the development, are presented in detail.

4.3.1 Use of Open Source Softwares and Freely-available Servers

Table 4.1 shows open source softwares involved in the development. *Joomla* is a content management system developed with PHP, which is a general-purpose scripting language for Web development, and uses MySQL database as its data storage. *Joomla* provides almost all the components the prototype system needs for its essential Web features: the homepage, the learning support subsystem, the membership management subsystem, forums, and interfaces to other subsystems and functions.

In addition, *Joomla* has many free extensions, to which many developers around the world contribute. For example, GCalendar, developed by Allon Moritz, using Google Calendar Data API, described in Section 2.3.2, offers a component which shows Google Calendars inside a Joomla-based web page. Kunena Forum (`http://www.kunena.com`) is one of the popular extensions in the forum category of *Joomla*. GCalendar and Kunena Forum are applied to the implementation of the system without modifications.

Blojsom is a Java-based multi-blog system combined with MySQL database. The *logbooks* presented in Equation (3.7) are implemented using this blog system. *Blojsom* has its own identification and authentication mechanism. Hence, to integrate this blog system into the learning support subsystem, based on *Joomla*, it is inevitable some modules and database tables, in both *Joomla* and *Blojsom*, will be added and modified.

Project Darkstar is an open source, online game server. It is responsible for communicating between game server and clients. It also maintains the last status of game objects the game server manages, and forms the infrastructure of the treasure hunt game. *Slick* is a Java-based 2-dimensional game development library through which one is able to easily access OpenGL, which is an API for creating 2D and 3D graphics. The Slick library manages the images and sounds of the treasure hunt game. The client portion of the game is implemented based on the Slick library.

Stendhal is an open source, multiplayer online adventure game. All the graphic images and sounds, implemented in the treasure hunt game, are obtained from *Stendhal*. The treasure hunt game world is also made up of 2-dimensional game maps and related XML codes taken from *Stendhal*. Thus, it is possible to remove a large amount of graphic related work and reduce a large amount of development time.

Table 4.2 presents the database and Web servers, installed to form the development environment. *Apache HTTP Server* is a freely-available HTTP (Web) server. Joomla-based web pages of *OTHI* run on this server. *Apache Tomcat* is a Java servlet container, which implements the Java Servlet and JavaServer Pages technologies. *Apache Tomcat* is responsible for the execution of *Blojsom* and the teaching support

Table 4.2: Database and Web servers implemented for the system.

Name	Version	Description	URL
Apache HTTP Server	2.2	HTTP/1.1 compliant web server	`http://httpd.apache.org/`
Apache Tomcat	6.0	Java servlet container	`http://tomcat.apache.org/`
MySQL	5.1	Database management system	`http://www.mysql.com/`
Berkeley DB	4.5	Embeddable database engine	`http://www.oracle.com/technology/products/berkeley-db/db/`

Table 4.3: Tools used in the design and development of the treasure hunt game.

Name	Version	Description	URL
BMFont	1.11b	Bitmap font generator	`http://www.angelcode.com/products/bmfont/`
NetBeans	6.5	Integrated development environment	`http://www.netbeans.org/`
Paint.net	3.36	Image and photo editing tool	`http://www.getpaint.net/`
StarUML	5.0.2	Software modeling tool	`http://staruml.sourceforge.net/en/`
Tiled	0.7.2	Tile map editor	`http://mapeditor.org/`

subsystem of *OTHI*. *MySQL* is a database server, and manages the user knowledge base. *Berkeley DB* is an embedded database with bindings in Java and manages the game data base.

4.3.2 Useful Tools and Other Technologies

In the design and development of the system, the tools, listed in Table 4.3, are very helpful. *StarUML* is an open source UML tool running on Win32 platform. It supports UML 2.0 and has four modeling approaches: 4+1 View Model, Default Approach, Rational Approach and UML Component. The treasure hunt game is designed with the Default Approach of this modeling tool. *NetBeans* is a modular, standards-based, integrated development environment (IDE) for Java developer. Its profile feature shows the CPU and memory usage of each Java class and method, and supports finding bottlenecks in the treasure hunt game. *BMFont* generates fonts for letters appearing in the game. *Paint.net* supports drawing and editing graphic images. *Tiled* is an editor for the 2-dimensional map and helps organize the 2D game map for the game.

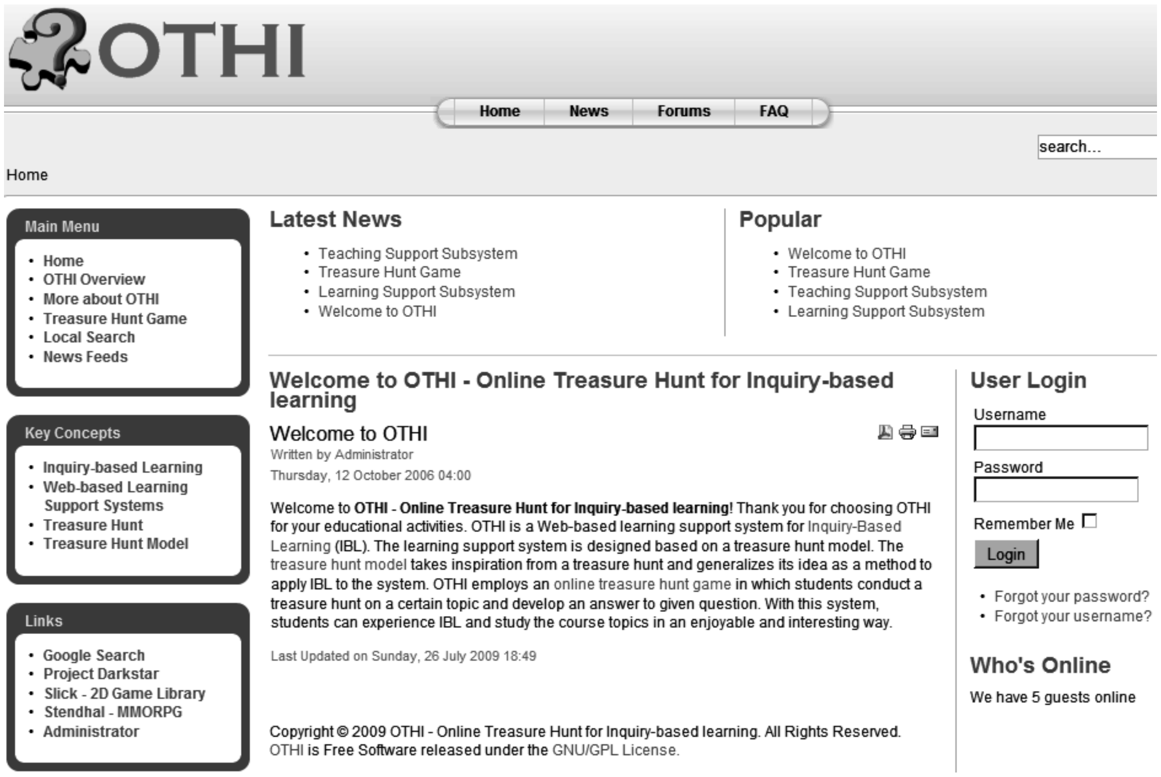
Table 4.4: Algorithms and other technologies applied to the treasure hunt game.

Name	**Description**	**URL**
A* Pathfinding Algorithm	Algorithm for path finding	
Dijkstra's Algorithm	Algorithm for path finding	
Java Web Start	Deploying Java applications to user	`http://java.sun.com/products/javawebstart/`
Porter stemmer	Algorithm for suffix stripping	`http://tartarus.org/~martin/PorterStemmer/`
XML	EXtensible Markup Language	`http://www.w3.org/XML/`

Table 4.4 lists a few algorithms and other technologies used in developing the game. *A* Pathfinding Algorithm* and *Dijkstra's Algorithm* are pathfinding algorithms. The game exploits the algorithms to give the most suitable paths to avatars which are digital characters moving forward in the game. *Porter stemmer* is an algorithm for suffix stripping, which is a crucial technology in a Web search engine. The game uses the algorithm to extract significant words from the question, sample answer and student answer in order to measure the similarity, as denoted in Equation (3.13). *Java Web Start* provides a method of deploying the game to the user. *XML* files work as the course knowledge base. Appendix C presents some important xml files of this system.

4.4 Implementation of Essential Features

OTHI has the following major components: the homepage, teaching support subsystem, learning support subsystem, treasure hunt game and membership management subsystem. There is no need to describe the membership management subsystem further. In this research, all the functions the subsystem provides are implemented by *Joomla Administration.* Some functions of the subsystem are treated in Section 4.4.1. One may refer to the *Joomla* website, specified in Table 4.1, if (s)he wishes more information. In this section, the implementation of the remaining components is presented.



Main Menu
- Home
- OTHI Overview
- More about OTHI
- Treasure Hunt Game
- Local Search
- News Feeds

Key Concepts
- Inquiry-based Learning
- Web-based Learning Support Systems
- Treasure Hunt
- Treasure Hunt Model

Links
- Google Search
- Project Darkstar
- Slick - 2D Game Library
- Stendhal - MMORPG
- Administrator

Latest News
- Teaching Support Subsystem
- Treasure Hunt Game
- Learning Support Subsystem
- Welcome to OTHI

Popular
- Welcome to OTHI
- Treasure Hunt Game
- Teaching Support Subsystem
- Learning Support Subsystem

Welcome to OTHI - Online Treasure Hunt for Inquiry-based learning

Welcome to OTHI
Written by Administrator
Thursday, 12 October 2006 04:00

Welcome to **OTHI - Online Treasure Hunt for Inquiry-based learning**! Thank you for choosing OTHI for your educational activities. OTHI is a Web-based learning support system for Inquiry-Based Learning (IBL). The learning support system is designed based on a treasure hunt model. The treasure hunt model takes inspiration from a treasure hunt and generalizes its idea as a method to apply IBL to the system. OTHI employs an online treasure hunt game in which students conduct a treasure hunt on a certain topic and develop an answer to given question. With this system, students can experience IBL and study the course topics in an enjoyable and interesting way.

Last Updated on Sunday, 26 July 2009 18:49

Copyright © 2009 OTHI - Online Treasure Hunt for Inquiry-based learning. All Rights Reserved.
OTHI is Free Software released under the GNU/GPL License.

User Login
Username
Password
Remember Me ☐
Login
- Forgot your password?
- Forgot your username?

Who's Online
We have 5 guests online

Figure 4.2: Homepage of OTHI.

4.4.1 Homepage of OTHI

As shown in Figure 4.2, the homepage consists of a logo, a top menu, Search, Main Menu, Key Concepts, Links, Latest News, Popular, and User Login. The *logo* signals the student to solve a puzzle and answer a question. Home, News, Forums and FAQ make up the *top menu*. The *Search* in the upper right-hand corner of the page performs a local search. The *Main Menu* provides Home, OTHI Overview, More about OTHI, Treasure Hunt Game, Local Search, and News Feeds. The *Key Concepts* furnish the system's background concepts such as: inquiry-based learning, Web-based learning support systems, treasure hunt and the treasure hunt model. The *Links* offer links to a few useful websites to obtain more information and a link to the administrator web page as well. The *Latest News* lists links to the latest news about

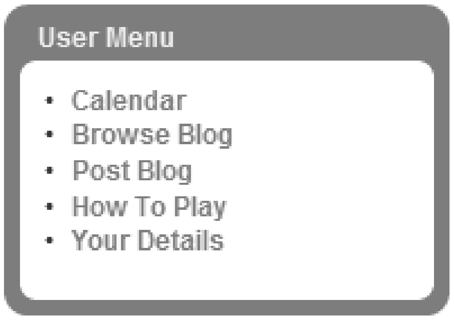


Figure 4.3: User Menu of student.

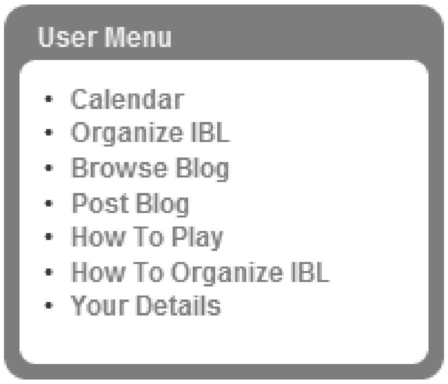


Figure 4.4: User Menu of instructor.

the system and the *Popular* shows links to the popular articles the website provides. The *User Login* has two input fields, Username and Password. When a user logs into the system, a User Menu appears above the Main Menu. A welcome message is displayed in the middle of the homepage.

Available content and features are restricted by the user group to which the user belongs. Figure 4.3 and Figure 4.4 show the instructor's User Menu containing more features than the student's User Menu. There are four Front-end User Groups: Registered, Author, Editor and Publisher. The content and features of *OTHI* are categorized by access levels: Public, Registered and Special. Only the Author, Editor, or Publisher group can access the special-level content and features. Instructors have the Publisher privilege of being allowed to access the teaching support subsystem through a menu *Organize IBL*, whose access level is the Special, while students are assigned to the Registered.

4.4.2 Teaching Support Subsystem

The teaching support subsystem (TSS) allows instructors to lay out their courses and build their own IBL environments into the treasure hunt game. Figure 4.5 shows

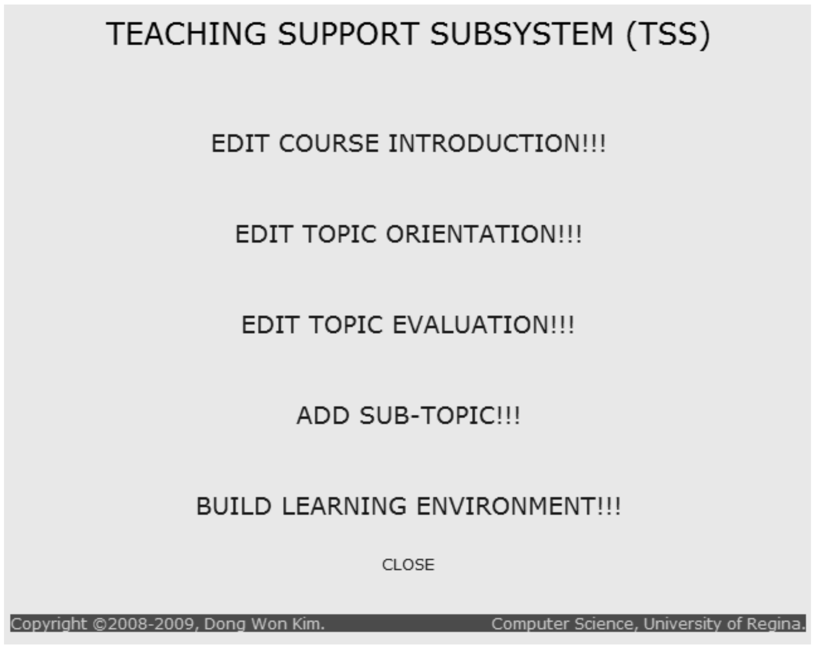

TEACHING SUPPORT SUBSYSTEM (TSS)
EDIT COURSE INTRODUCTION!!!
EDIT TOPIC ORIENTATION!!!
EDIT TOPIC EVALUATION!!!
ADD SUB-TOPIC!!!
BUILD LEARNING ENVIRONMENT!!!
CLOSE
Copyright ©2008-2009, Dong Won Kim.
Computer Science, University of Regina.

Figure 4.5: Main menu of TSS.

the main features of TSS as follows.

1. **Edit Course Introduction**. The instructor inputs the course title, course objectives and course references on the Edit Course Introduction page, as described in Algorithm 1.

2. **Edit Topic Orientation**. On the Edit Topic Orientation page, the instructor edits the topic title, introduction and question which is offered to a student by an NPC at an orientation station.

3. **Edit Topic Evaluation**. On the Edit Topic Evaluation page, the instructor enters a topic conclusion and a sample answer to the question, which the instructor presented on the Edit Topic Orientation page. In addition to the conclusion and sample answer, a clue, which directs the student to the evaluation station of the topic, is also specified on the Edit Topic Evaluation page.

4. **Add Sub-Topic**. The instructor defines a sub-topic title, a description of the sub-topic and a clue on the Add Sub-Topic page. The description is the core information regarding the sub-topic. The instructor may consider a two or four-line rhymed clue which is ambiguous enough to hide its meaning at first glance, but stimulate students to discover the meaning. The clue will direct the student to the help station of the sub-topic.

5. **Build Learning Environment**. Build Learning Environment enables the instructor to define connections between the information specified on the Edit Topic Orientation, Edit Topic Evaluation and Add Sub-Topic pages, and game objects in the treasure hunt game. The instructor also defines the learning order relationship between concepts by using the field "Next stations" on the Build Learning Environment page.

Those definitions are converted into records in XML files that are inputs to the game. Appendix C presents the XML files. Algorithm 7 depicts Edit Topic Orientation, Edit Topic Evaluation and Add Sub-Topic features. Build Learning Environment feature is described in Algorithm 5 and Algorithm 6, as detailed in Section 4.2.1.

4.4.3 Learning Support Subsystem

The learning support subsystem supports both the treasure hunt and IBL of each student. The subsystem also provides topic resources for students and aides them in managing the complex, extended activities of the treasure hunt. The following is the available features of the subsystem.

1. **Calendar**. As described in Section 2.3.2, the calendar enables the student to make an appointment with others to collaborate in the treasure hunt. Once a student creates a Google Calendar and the system administrator enrolls its

Calendar ID through the *Joomla Administration*, other people can share the calendar.

2. **Browse Blog**. It opens a *blog* window and allows the student to read articles posted by the system, as well as by the student.

3. **Post Blog**. The student posts new articles and revises old articles through this feature. As previously described, the *blog* works as the *logbook* of the treasure hunt model.

4. **Google Search**. *Google Search* supports students in finding the resources for the treasure hunt. The *Links* in the lower left-hand corner of Figure 4.2 include a link to the *Google Search*.

To attach Browse Blog and Post Blog features, implemented with *Blojsom* package, to the homepage based on *Joomla*, a Joomla component is developed using a programming language *PHP*. Appendix D contains the program sources.

4.4.4 Treasure Hunt Game

Treasure hunt game is a 2-dimensional multiplayer online learning game developed with Java and its client program is deployed using Java Web Start. Its JNLP (Java Network Launching Protocol) definition is presented in Appendix C.9. When the game server is started, it loads all configurations about game objects into memory, including the course definitions, from the XML files, presented in Appendix C, and initializes the game objects, as denoted in lines **77-85** of Appendix E.2. Appendix E contains: the server main program, client main program, authentication server program and database definition program. The database definition program provides database and table information necessary to process the authentication of players,

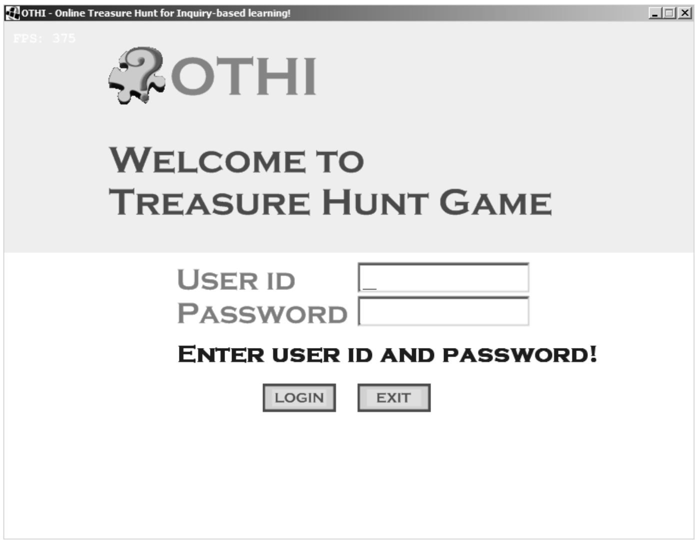
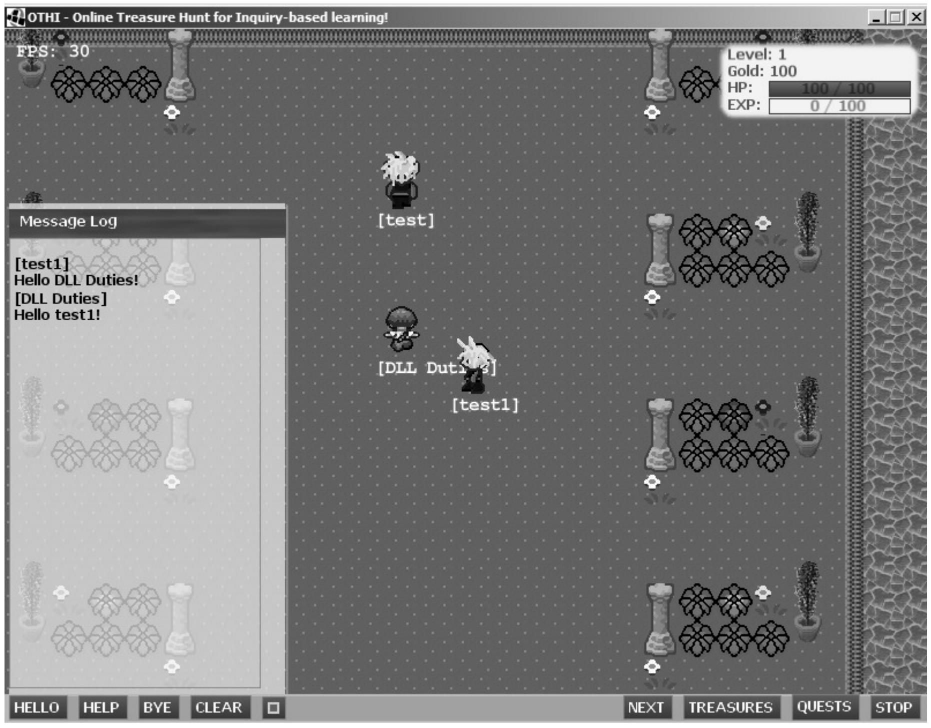

OTHI - Online Treasure Hunt for Inquiry-based learning!
FPS: 375
OTHI
WELCOME TO
TREASURE HUNT GAME
USER ID
PASSWORD
ENTER USER ID AND PASSWORD!
LOGIN
EXIT

Figure 4.6: Login screen of the treasure hunt game.

using the authentication server program, and manage the *blog* data. The client main program specifies the server ip address and tcp port number to connect.

As denoted in Section 4.2.2, Algorithm 8 shows the game's major functions. Players can access the treasure hunt game through the authentication process, as shown in Figure 4.6. Basically, a player tries to find a hidden treasure, denoted in a quest with given clues, exploring the game world and overcoming challenges. If the player acquires enough experience points, (s)he can level up, become stronger and faster, and is allowed to equip herself/himself with higher level weapons and armors. Completing the quests, overcoming challenges, and finding treasures give the player rewards and experience points. Some equipment, tools, and aids are required in order to find the treasures and defeat the monster which is considered to be one of the *obstacles* in the treasure hunt model. The player can buy those valuable items with golds, acquired as rewards.

The hidden treasure may be an appropriate answer to the question presented in a quest. The quest is a request the player explores and finds the answer by visiting



[test1]
Hello DLL Duties!
[DLL Duties]
Hello test1!

Figure 4.7: Multiple users of the treasure hunt game.

stations and constructing ideas. The Non-Player Character (NPC) works as the guide and personifies one of the sub-topics of the topic. The names and places of all NPCs in the game world may consist of words relevant to the sub-topics. If the player meets an NPC and the help event occurs, the NPC tells the player the description of a sub-topic and a clue for the next station. It offers an opportunity to further investigate the given question and learn the topic in-depth. The treasure hunt game posts the information, provided by the NPC, to the *blog*, as mentioned in Section 3.3.3. Each found treasure causes an evaluation event, in which the player should take a test and give the answer developed by the treasure hunt. The test score demonstrates the student's understanding of the topic. A lack of score results is a failed quest.

Figure 4.7 is a screenshot of the treasure hunt game, showing multiple users logged on. There is an orange bar called Control Panel on the bottom of the screenshot.

It has nine buttons. HELLO, HELP and BYE buttons are required to conduct a conversation with an NPC. The HELLO button attracts the NPC's attention, makes the NPC stop moving, and starts a conversation with the NPC. The HELP button asks the NPC for the *information*, addressed in Equation (3.7). The BYE button ends the conversation and allows the NPC to go on its way.

The conversations between the player and the NPC are left in a message log. The Message Log window, on the left side of Figure 4.7 allows the conversations in the message log to be displayed on the game screen. The CLEAR button on the Control Panel empties the message log. A small button on the right side of the CLEAR button disables and enables the Message Log window. A list of the next learnable objects is displayed when the player clicks the NEXT button. The TREASURES button displays the information regarding the treasures found by the player, and the QUESTS button displays the information about the quests the player has received from the NPCs. The STOP button halts the playing of the game.

A left click of the mouse points to a spot where the player's avatar moves toward. If the player's avatar is close enough to attack a monster, a check symbol is displayed when the mouse hovers over the monster. A right click of the mouse attacks the monster if the check symbol is on it. If the player's avatar is near a treasure box, it is opened by left clicking on the treasure box and the player takes note if it has a treasure. Every avatar has one name appearing on the bottom of it. When the mouse is over the avatar, its game level is also displayed.

A status panel is always displayed in the upper right-hand corner of the game screen, as shown in Figure 4.7. The status panel depicts the status of the player in the game with the following information: Level, Gold, HP and EXP. The Level shows the game level of the player and the Gold indicates how many golds the player has. HP stands for Health Points, and the player cannot move for a while if the HP is zero due to an attack from a monster. The EXP represents the experience points a player has obtained. If the EXP bar is full, the player levels up, the EXP is set to zero, and the maximum of the HP is increased.

4.4.5 Dependence of the Treasure Hunt Game on Learning

Students are eager to receive a quest, prepare for an answer, find a treasure, and answer the open question, since they receive a better reward from completing a quest than from hunting monsters. Suppose a level-one player tries to level up by hunting rats. The player must hunt 100 rats and spends a great deal of time, taking care of the health points. Hunting a rat requires the player to hit the rat ten times at sacrificing of his/her health points, just offers the player one experience point and drops a cheese or some golds if the player is lucky.

On the contrary, as represented in Figure 4.12, a quest reward may include 1,000 golds and 500 experience points, which is sufficient for a one-level player to level up. If the player receives remarkable marks for the question, the reward includes one of the following: a tool, an equipment, an armor or a weapon. After completing the quest, the player becomes a level-two player who can hunt the rat by hitting it only once. The rats can no longer prohibit the player from finding other treasures. The player may challenge higher level of treasures. Students quickly come to recognize learning a topic is the best way to upgrade their avatars and to win respect from other students.

4.5 A Demonstrative Example

This section depicts how each feature of the system works for learning in a data communications and network course. Suppose an instructor prepares a lecture regarding the *data link layer* (DLL) of the course using the TSS; the topic must be the data link layer.

4.5.1 Finding Learning Order Relationships

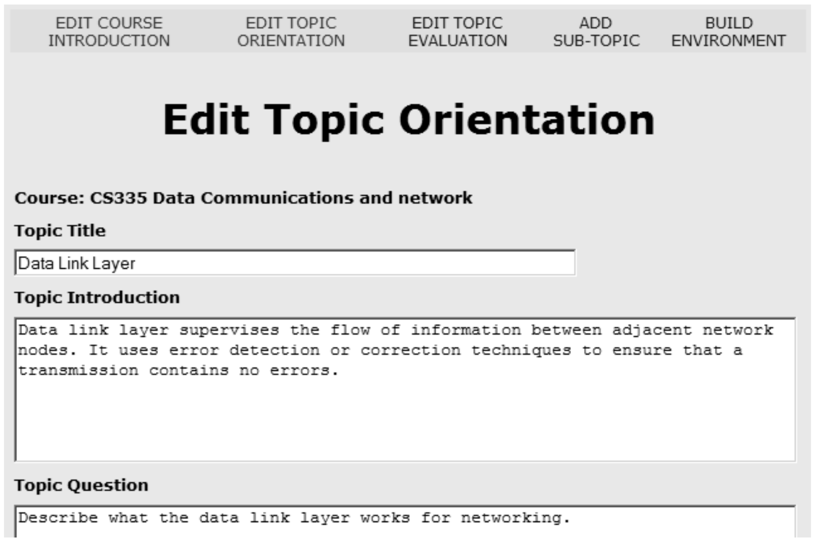
According to the instructor's lecture notes on the data link layer, the instructor may have the following learning objects: DLL introduction, DLL duties, error detection, flow control, parity checking, etc. In addition, the learning order relationships between the objects, are obtained using the learning order relation $\preceq$, given by Equation (3.4), on the set of the objects as follows:

$$\begin{aligned}&\text{DLL Introduction} \preceq \text{DLL Duties}, \text{DLL Duties} \preceq \text{Error Detection},\\&\text{DLL Duties} \preceq \text{Flow Control}, \text{Error Detection} \preceq \text{Parity Checking},\\&\text{Flow Control} \preceq \text{Parity Checking}.\end{aligned}$$

Since the object "DLL Duties" has two outer fringes – Error Detection and Flow Control – from the learning order relationships, the instructor can determine two possible learning paths: 1) DLL introduction → DLL Duties → Error Detection → Flow Control → Parity Checking; and 2) DLL introduction → DLL Duties → Flow Control → Error Detection → Parity Checking. The instructor may allow students to choose one of the two paths by defining the two objects as the outer fringes of "DLL Duties." Otherwise, the instructor fixes the learning path by choosing one. In this case, the first learning path is chosen.

4.5.2 Editing Topic Information

Before defining a topic using the Edit Topic pages shown in Figure 4.8 and Figure 4.9, the instructor must select a course, which is already defined on the Edit Course Introduction of TSS. Similarly, to define a sub-topic with the Add Sub-Topic of TSS, the instructor is also required to select both a course and a topic, to which the sub-topic belongs. For the learning object "DLL introduction," the instructor enters the topic title with "Data Link Layer," and also its introduction and question



Edit Topic Orientation

Course: CS335 Data Communications and network

Topic Title

Data Link Layer

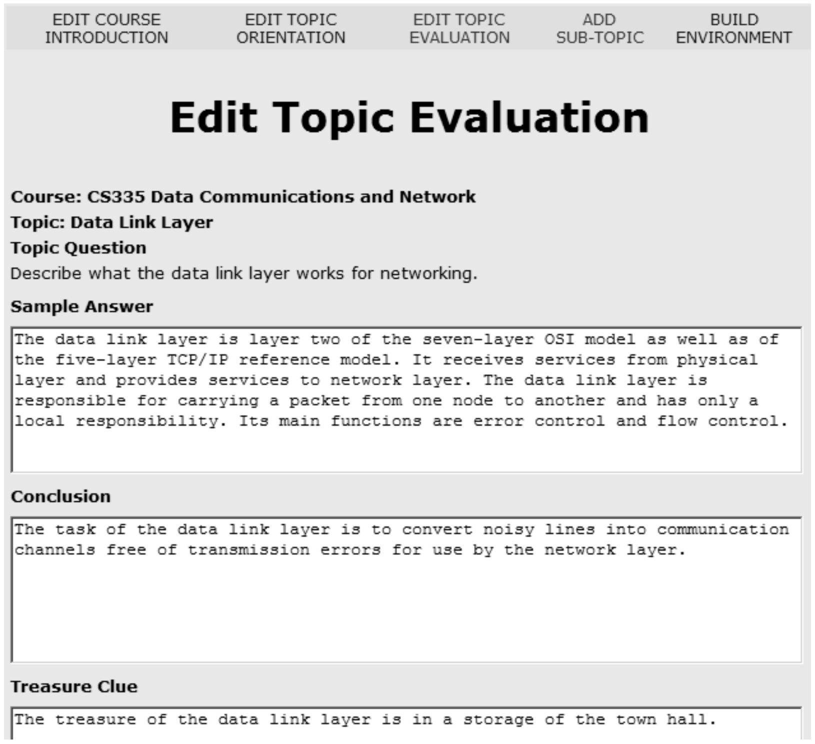
Topic Introduction

```
Data link layer supervises the flow of information between adjacent network
nodes. It uses error detection or correction techniques to ensure that a
transmission contains no errors.
```

Topic Question

```
Describe what the data link layer works for networking.
```

Figure 4.8: Edit Topic Orientation of TSS.



Edit Topic Evaluation

Course: CS335 Data Communications and Network

Topic: Data Link Layer

Topic Question

Describe what the data link layer works for networking.

Sample Answer

```
The data link layer is layer two of the seven-layer OSI model as well as of
the five-layer TCP/IP reference model. It receives services from physical
layer and provides services to network layer. The data link layer is
responsible for carrying a packet from one node to another and has only a
local responsibility. Its main functions are error control and flow control.
```

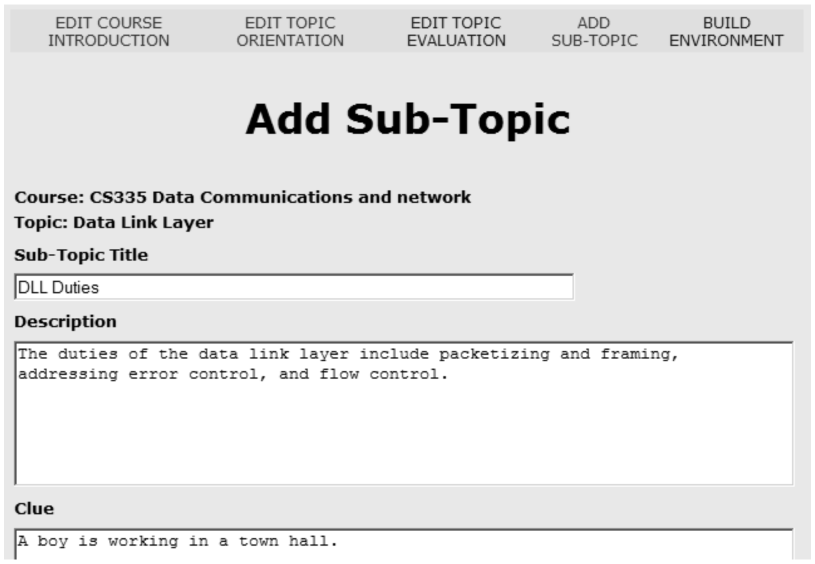
Conclusion

```
The task of the data link layer is to convert noisy lines into communication
channels free of transmission errors for use by the network layer.
```

Treasure Clue

```
The treasure of the data link layer is in a storage of the town hall.
```

Figure 4.9: Edit Topic Evaluation of TSS.



Add Sub-Topic

Course: CS335 Data Communications and network
Topic: Data Link Layer

Sub-Topic Title

DLL Duties

Description

```
The duties of the data link layer include packetizing and framing,
addressing error control, and flow control.
```

Clue

```
A boy is working in a town hall.
```

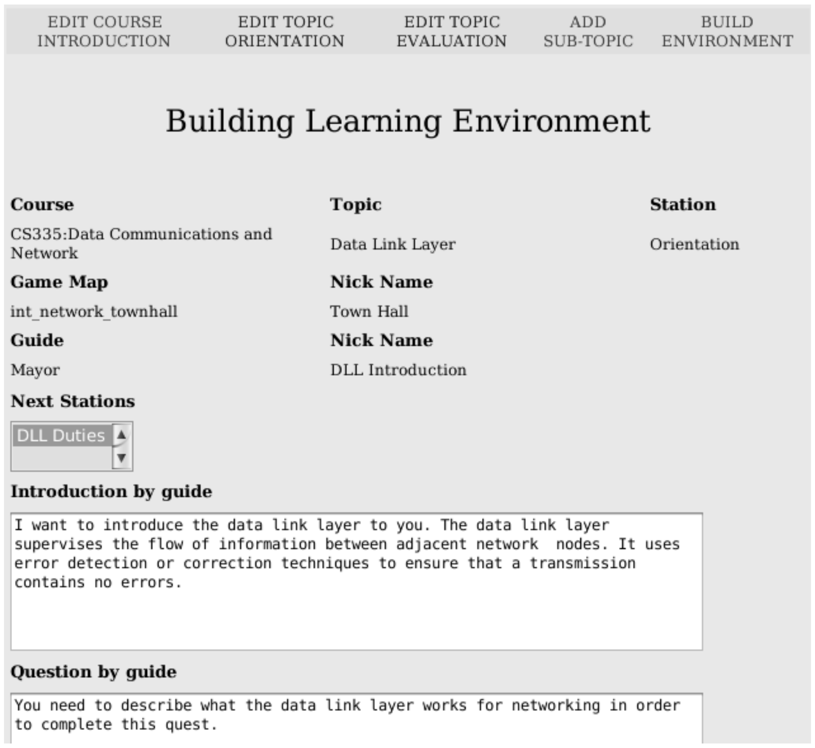
Figure 4.10: Add Sub-Topic for the sub-topic DLL Duties.

on the Edit Topic Orientation page as depicted in Figure 4.8. Appendix C.3 shows the output of this work. On the Edit Topic Evaluation page, the instructor enters a sample answer to the question presented on the Edit Topic Orientation page, a conclusion of the topic and a clue as to its evaluation station. Its results are displayed in Appendix C.4.

Other learning objects, except for "DLL introduction," become the sub-topics of the data link layer. The instructor defines the sub-topics on the Add Sub-Topic pages. Figure 4.10 shows the definition of a sub-topic "DLL Duties." The instructor enters its title and description, and also a clue as to its help station. Other sub-topic definitions can be performed in a similar manner. The results are shown in Appendix C.5.

4.5.3 Building an IBL Environment

Once the instructor finishes making up a topic with the Edit Topic Orientation, Edit Topic Evaluation and Add Sub-Topic pages, the instructor must build a learning



Building Learning Environment

Course
CS335:Data Communications and Network

Topic
Data Link Layer

Station
Orientation

Game Map
int_network_townhall

Nick Name
Town Hall

Guide
Mayor

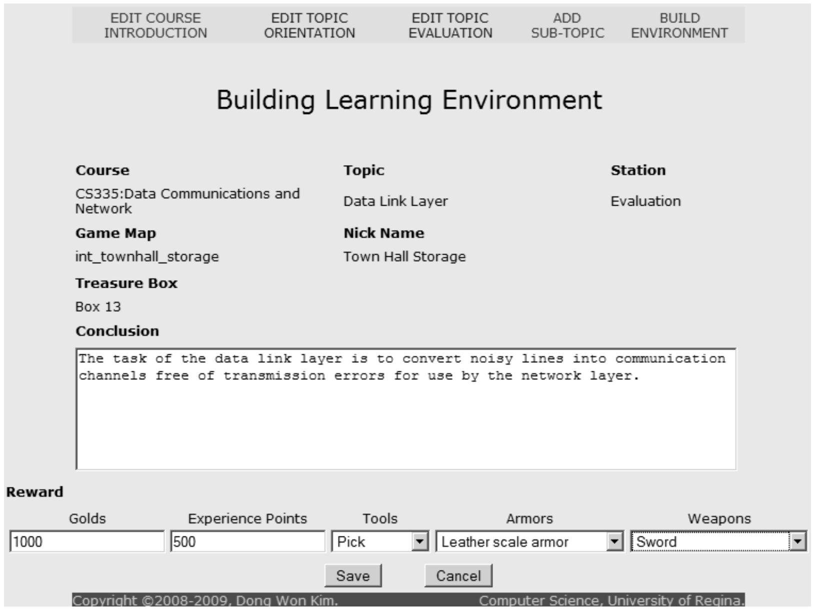
Nick Name
DLL Introduction

Next Stations
DLL Duties

Introduction by guide
I want to introduce the data link layer to you. The data link layer supervises the flow of information between adjacent network nodes. It uses error detection or correction techniques to ensure that a transmission contains no errors.

Question by guide
You need to describe what the data link layer works for networking in order to complete this quest.

Figure 4.11: Build Learning Environment for orientation



Building Learning Environment

Course
CS335:Data Communications and Network

Topic
Data Link Layer

Station
Evaluation

Game Map
int_townhall_storage

Nick Name
Town Hall Storage

Treasure Box
Box 13

Conclusion
The task of the data link layer is to convert noisy lines into communication channels free of transmission errors for use by the network layer.

Reward

Golds	Experience Points	Tools	Armors	Weapons
1000	500	Pick	Leather scale armor	Sword

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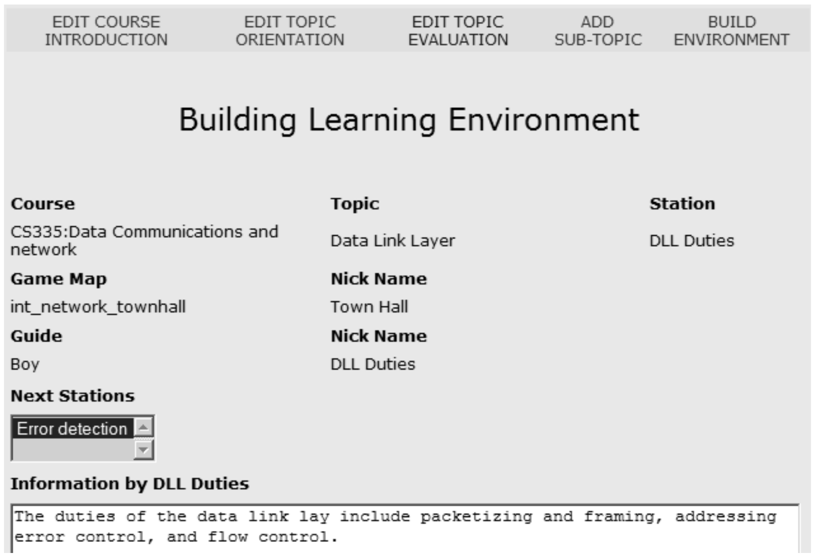
Figure 4.12: Build Learning Environment for evaluation.



Building Learning Environment

Course	**Topic**	**Station**
CS335:Data Communications and network	Data Link Layer	DLL Duties
Game Map	**Nick Name**	
int_network_townhall	Town Hall	
Guide	**Nick Name**	
Boy	DLL Duties	

Next Stations

Error detection

Information by DLL Duties

```
The duties of the data link lay include packetizing and framing, addressing
error control, and flow control.
```

Figure 4.13: Build Learning Environment for sub-topic DLL Duties.

environment into the treasure hunt game for the topic, using the Build Learning Environment of TSS. As shown in Figure 4.11, for the topic “Data Link Layer,” the instructor assigns a game map “Town Hall” as the orientation station and NPC “Mayor” as the guide, in accordance with the learning object allocation function, defined in Equation (3.10). The instructor also modifies the introduction of the topic to simulate a conversation. For the evaluation station, the instructor chooses a treasure box, “Box 13,” in “Town Hall Storage,” and sets 1,000 gold, 500 game experience points and so on, as a reward for the quest, as depicted in Figure 4.12.

Meanwhile, according to the building definition of “DLL Duties,” shown in Figure 4.13, NPC “Boy” in “Town Hall” will deliver the description, shown in Figure 4.10, to the students. Sub-topic “Error Detection,” specified in the field “Next Stations,” is an outer fringe of the sub-topic. The combination of game objects and corresponding learning objects is described in Table 4.5. Table 4.5 lists the related events, stations, game objects and learning objects. Appendix C.6, Appendix C.7 and Appendix C.8 are the results of this work.

Table 4.5: Combination of game components and learning objects.

Events	**Stations**	**Game Objects**	**Learning Objects**
Orientation	Town Hall	NPC Mayor	DLL Introduction
Help	Town Hall	NPC Boy	DLL Duties
Help	Network City	NPC Alice	Error Detection
Obstacle	Network Library Entrance	Rats	
Help	Network Library	NPC Monogenes	Flow Control
Obstacle	Town Hall Storage Entrance	Rats	
Evaluation	Town Hall Storage	Box 13	Conclusion

4.5.4 Experiencing IBL

Figure 4.14 shows a journey to the treasure of the data link layer. In the game world, the name of the learning object each NPC will deal with is displayed as the name of the NPC. From the orientation function, defined in Equation (3.11), as depicted in Figure 4.15, a student receives the quest about the data link layer from a NPC “DLL Introduction,” including the background information and question. The student posts what (s)he has understood, with the orientation information, to the *blog* as the writing idea function, described in Equation (3.20). To write an idea about it, the student may search for more information with key words “data link layer” or “introduction data link layer” using the *Google Search*.

After posting the idea, the learning object “DLL introduction,” indicated in Table 4.5, is added to the knowledge state of the student according to the experience interpretation function expressed in Equation (3.18). For the next available sub-topics, there is only one sub-topic available, “DLL Duties,” in accordance with the building definition for the orientation shown in Figure 4.11. Hence, NPC “DLL Introduction” tells the student the clue: “A boy is working in a town hall.” The student finds the boy called “DLL Duties” in a town hall.

When the student meets NPC “DLL Duties,” as described by Equation (3.12), (s)he may learn the basic duties of the data link layer from the NPC. To gain further

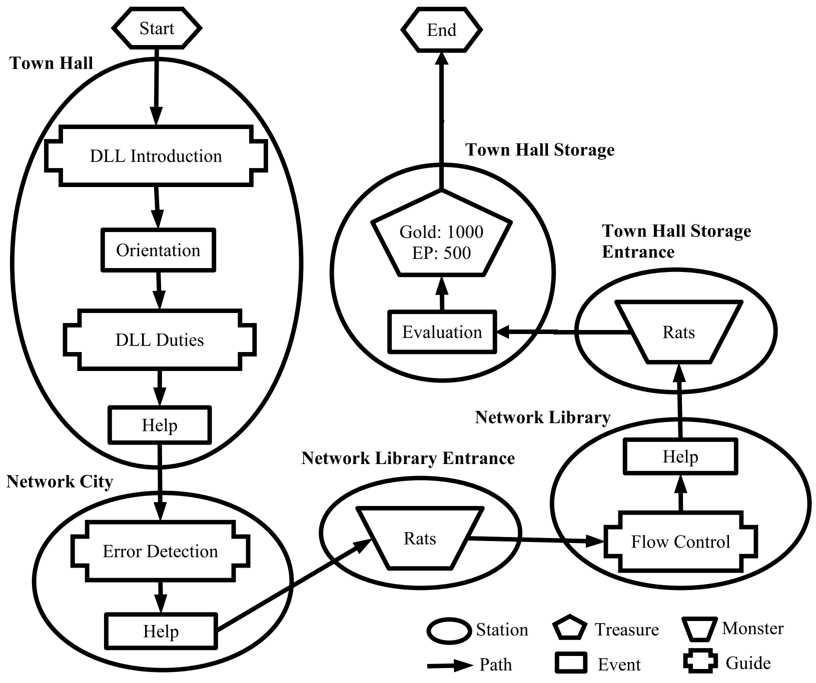
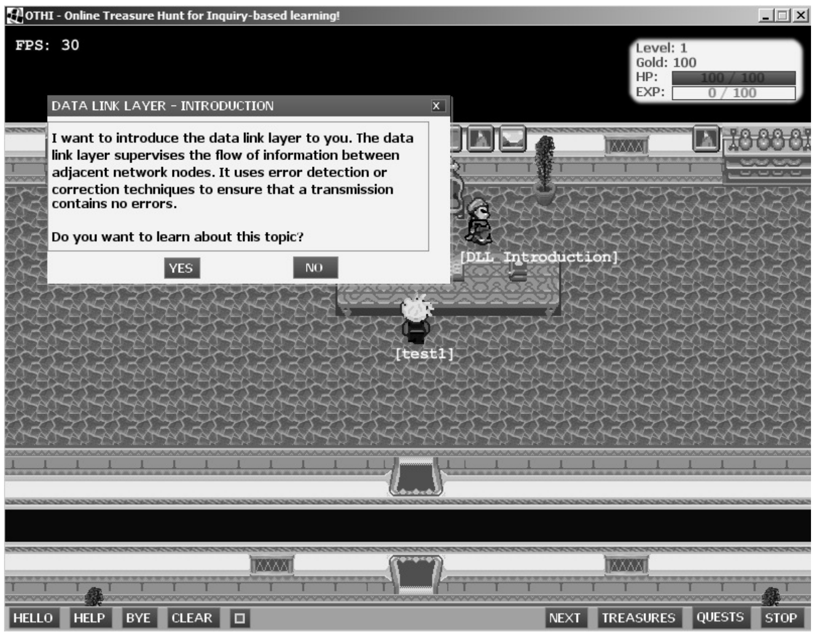


Figure 4.14: A Treasure Map.



I want to introduce the data link layer to you. The data link layer supervises the flow of information between adjacent network nodes. It uses error detection or correction techniques to ensure that a transmission contains no errors.

Do you want to learn about this topic?

Figure 4.15: Orientation for Data Link Layer in the treasure hunt game.

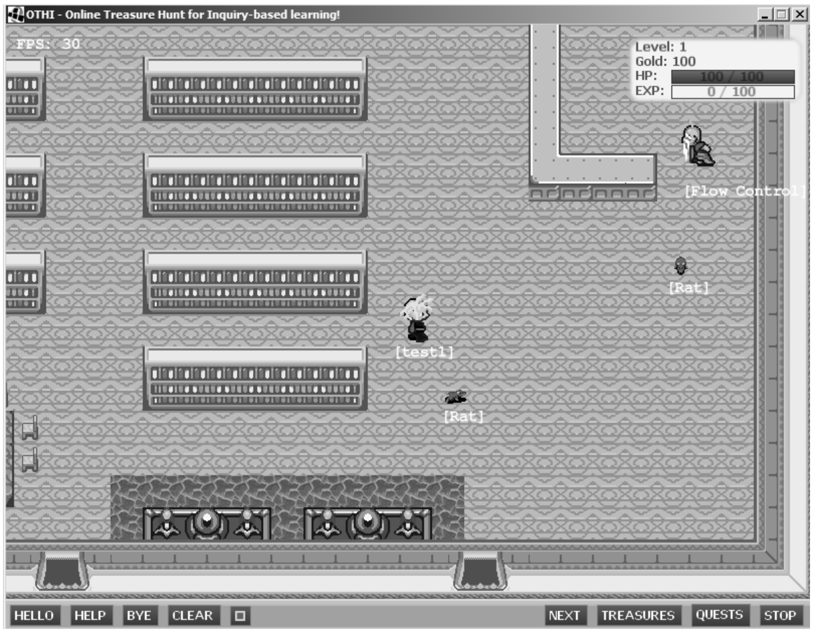
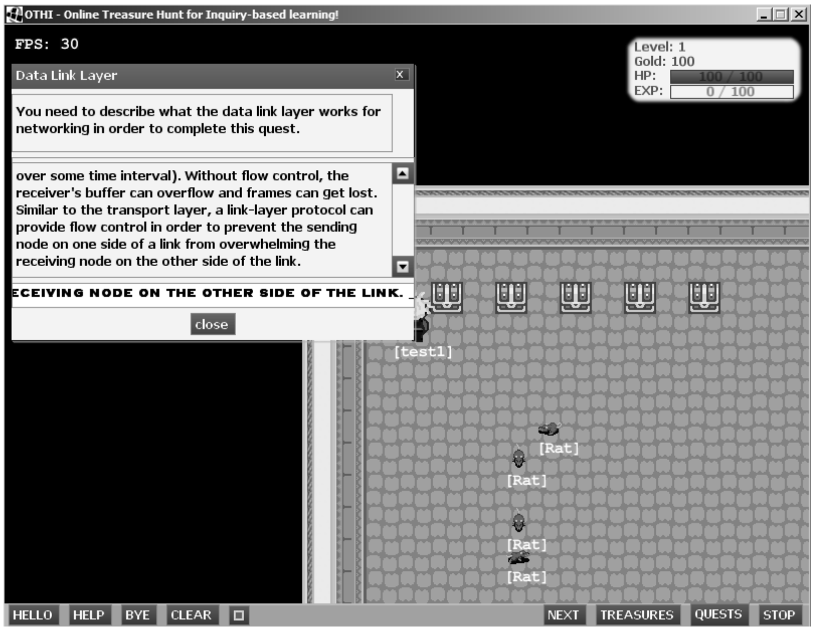


Figure 4.16: Rats at Network Library in the treasure hunt game.

understanding, the student searches for additional information, relevant to the sub-topic "DLL Duties," using the search engine. Then, the idea regarding the sub-topic is posted to the *blog*, and the sub-topic becomes a member of the knowledge state of the student. For the next sub-topic "Error Detection", NPC "DLL Duties" gives the student the clue: "A woman is waiting for you in a city." The student moves to find the woman called "Error Detection" in a city.

The woman can be found in "Network City." The woman talks about the error detection of the data link layer and shows a clue for NPC "Flow Control" as the next object to learn. The student meets rats when (s)he tries to enter the "Network Library" on the way to find NPC "Flow Control," as shown in Figure 4.16. The student is required to defeat the rats in order to enter this place and check if the NPC is there. According to the obstacle function, defined in Equation (3.15), some experience points are obtained as the student expels the rats using his/her weapons.

After overcoming all the challenges, the student finds a treasure box in "Town Hall


OTHI - Online Treasure Hunt for Inquiry-based learning!

FPS: 30

Level: 1
Gold: 100
HP: 100 / 100
EXP: 0 / 100

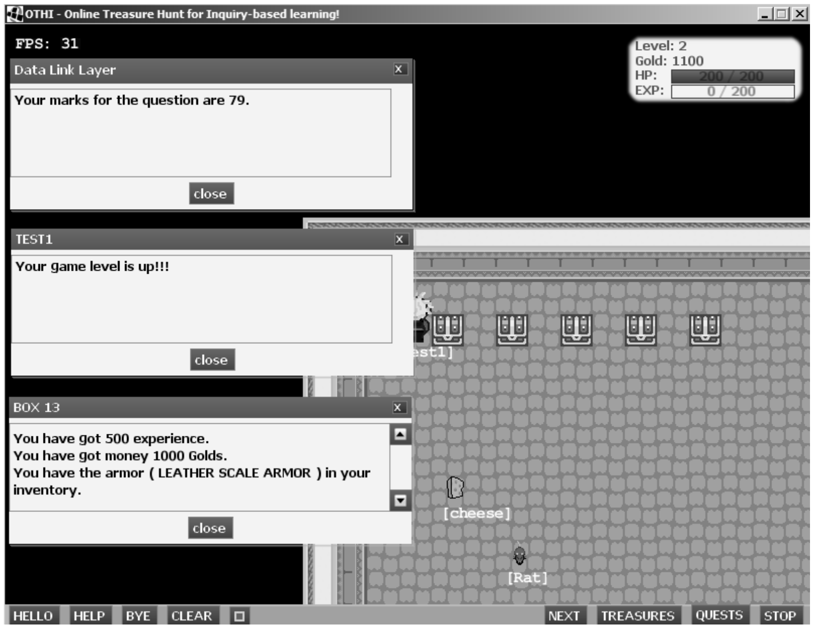
Data Link Layer

You need to describe what the data link layer works for networking in order to complete this quest.

over some time interval). Without flow control, the receiver's buffer can overflow and frames can get lost. Similar to the transport layer, a link-layer protocol can provide flow control in order to prevent the sending node on one side of a link from overwhelming the receiving node on the other side of the link.

ECEIVING NODE ON THE OTHER SIDE OF THE LINK.

Figure 4.17: Ask for an answer in the treasure hunt game.


OTHI - Online Treasure Hunt for Inquiry-based learning!

FPS: 31

Level: 2
Gold: 1100
HP: 200 / 200
EXP: 0 / 200

Data Link Layer

Your marks for the question are 79.

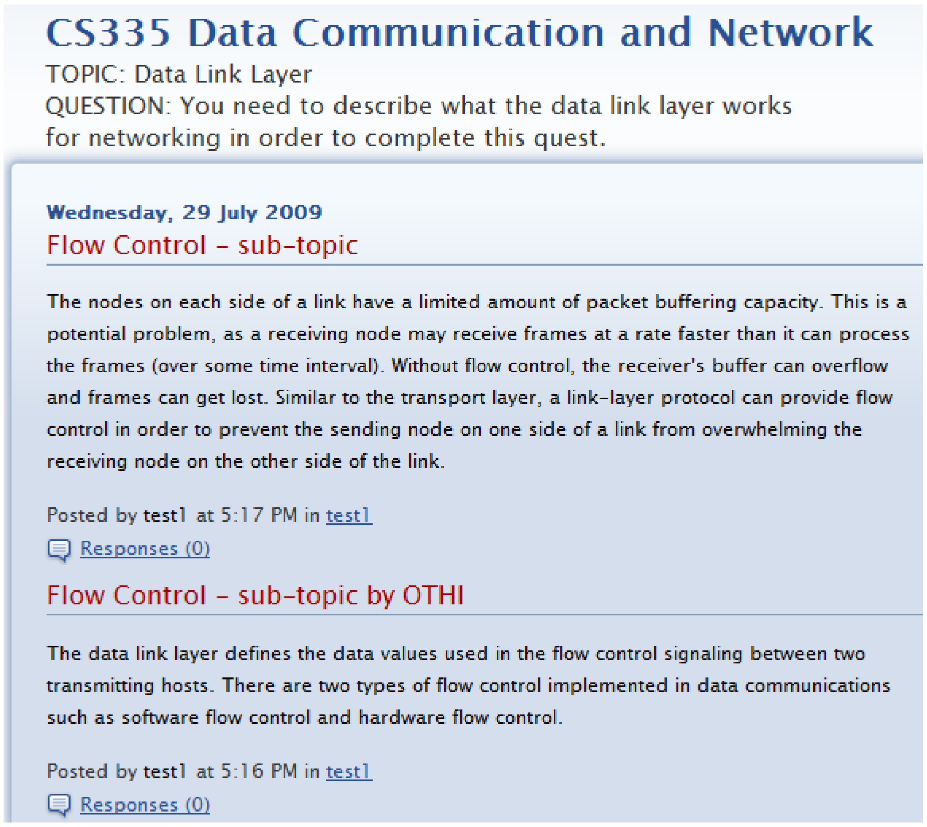
TEST1

Your game level is up!!!

BOX 13

You have got 500 experience.
You have got money 1000 Golds.
You have the armor (LEATHER SCALE ARMOR) in your inventory.

Figure 4.18: Complete a quest in the treasure hunt game.


CS335 Data Communication and Network

TOPIC: Data Link Layer

QUESTION: You need to describe what the data link layer works for networking in order to complete this quest.

Wednesday, 29 July 2009

Flow Control - sub-topic

The nodes on each side of a link have a limited amount of packet buffering capacity. This is a potential problem, as a receiving node may receive frames at a rate faster than it can process the frames (over some time interval). Without flow control, the receiver's buffer can overflow and frames can get lost. Similar to the transport layer, a link-layer protocol can provide flow control in order to prevent the sending node on one side of a link from overwhelming the receiving node on the other side of the link.

Posted by test1 at 5:17 PM in test1

Responses (0)

Flow Control - sub-topic by OTHI

The data link layer defines the data values used in the flow control signaling between two transmitting hosts. There are two types of flow control implemented in data communications such as software flow control and hardware flow control.

Posted by test1 at 5:16 PM in test1

Responses (0)

Figure 4.19: Blog posts about sub-topic Flow Control.

Storage." When the student opens it, as shown in Figure 4.17, (s)he is asked to give an answer to the question to complete this quest in accordance with the evaluation function described in Equation (3.14). For the treasure, as defined in Figure 4.12, the student may gain 1,000 gold and 500 game experience points if (s)he passes. Figure 4.18 represents the student achieving 79 points for the question. Enough experience points enable the student to *level up*. The gold the student received will be spent on arms to help defeat the *obstacles* (s)he will face in the next round of the treasure hunt. The game level of the student is one of the measures indicating how well (s)he has performed learning.

As previously described, during the journey to the treasure hunt, the student is required to write his/her idea about each sub-topic in the *blog*. Each post to the *blog* forms the idea structure, defined in Equation (3.19). Figure 4.19 shows the blog posts about the sub-topic “Flow Control,” written by the system, as well as by the student. “Flow Control” is the subject and the “sub-topic” represents the relationship of the idea structure. The posts also contain comments below the subject portions. The question is shown on top of the *blog*. This mechanism can help the student organize ideas about the question and give the appropriate answer when the student finds the treasure and takes the test.

4.6 Usefulness of OTHI for Learning

The usefulness of fully implemented OTHI can be shown by means of contrastive evaluation of OTHI supported learning against other learning approaches: traditional face-to-face classroom learning (TFCL), and passive, asynchronous Web-based learning (PAWL). The evaluation was performed by investigating the comparative advantages and disadvantages of each learning approach in previous studies related to Web-based learning, inquiry-based learning, or learning games.

The following five attributes were developed to deal with the pros and cons of the learning approaches.

1. **Availability**: Learning availability, including the accessibility and reuseability of learning services.

2. **Flexibility**: Flexibility and adaptability of learning content and process, according to students’ individual needs.

3. **Interactivity**: Real-time interactivity between students and instructors or learning content, and among students.

4. **Motivation**: Learning motivation and engagement, encouraging students to actively participate in learning.

5. **Student-centricity**: Student-centricity in the process of teaching and learning.

Table 4.6 presents the results found in an investigation of the evaluation. Each learning approach was evaluated and classified (low, medium, high) based on its comparative advantages and disadvantages as reported in the literature for the attributes and compared with the other learning approaches. The first column lists the evaluation attributes, and the values of the attributes for each learning approach are found in the second, third, fourth and fifth columns. The last column parades the literature from which the results are served for each attribute.

The availability of TFCL is relatively low when compared with other learning approaches, while PAWL shows a high availability of learning services. The OTHI supported learning approach may include either PAWL or TFCL. If OTHI supports students in PAWL, its availability is the same as the availability of PAWL. Otherwise, if OTHI supports students in TFCL, the overall availability of the learning services cannot attain the availability of the pure web-based learning due to the low availability of TFCL, in spite of the support of OTHI to improve the availability.

Previous studies reported TFCL provides students with higher flexibility and interactivity than PAWL. In a traditional classroom, if a student does not understand a particular section of a learning material, the student can raise questions and receive an immediate presentation about the material from the teacher who uses an example, a story, or just more detail. The teacher can adapt content and pace to the rate at

Table 4.6: Comparative and contrastive evaluation of OTHI and other learning approaches.

Evaluation attributes	**Traditional learning (TFCL)**	**Web-based learning (PAWL)**	**TFCL with OTHI**	**PAWL with OTHI**	**Related research papers**
Availability	Low	High	Medium	High	[2, 10, 12, 26, 37, 75, 84, 86]
Flexibility	High	Low	High	Medium	[6, 10, 12, 21, 33, 50, 75, 85, 86]
Interactivity	High	Low	High	Medium	[10, 11, 28, 33, 34, 42, 56, 62, 65, 68, 85]
Motivation	Medium	Low	High	High	[3, 13, 17, 30, 31, 33, 35, 38, 58, 62, 66, 69, 71]
Student-centricity	Low	Medium	High	High	[18, 21, 22, 26, 31, 37, 39, 68, 74, 86]
Total	10	8	14	13	(Low=1, Medium=2, High=3)

which students understand the material. In PAWL, neither the instructor nor the delivery system can adapt the course presentation to different students, and online students perceive less interactivity compared to students in the traditional classroom.

On the other hand, the features of OTHI (such as the *learning state*, forum, Web search engine and online treasure hunt game) are able to enhance the flexibility and interactivity of PAWL. A student who uses OTHI in learning is able to find and learn appropriate topics based on his/her *learning state*, and does not need to waste time learning irrelevant or already known material. In addition, the student cannot only find appropriate answers to questions about the topics at the forum or on the Web using the search engine, but is also able to receive instant feedback regarding the questions from other students who have already investigated the questions in the treasure hunt game. The *guide*, an animated character [65], in the treasure hunt game provides a more interactive learning experience to the student. Nevertheless, PAWL with OTHI cannot attain the flexibility and interactivity of TFCL, unless the animated character can compete with the human instructor.

As for the motivational aspect of the learning approaches, TFCL is more motivational than PAWL. Zhang *et al.* [86] specified that one of the advantages of TFCL is "motivating students," as compared to PAWL. Furthermore, previous studies on Web-based learning reported PAWL makes it difficult for students to become motivated for learning.

OTHI supported learning provides students with higher motivation for learning than TFCL. Learning games can enhance students' learning motivation when applied in classrooms or other learning scenarios. Particularly, online-learning games can arouse the motivation of the students by their enjoyment of playing the game and learning a topic at the same time. The online treasure hunt game of OTHI can be a valuable learning motivator and promote learning motivation. Furthermore, the inquiry activities that the game furnishes can create a motivation to learn. The *guide* works as an animated pedagogical character [64, 13] and also helps to increase the student's motivation and engagement.

TFCL exhibits relatively lower student-centricity, representing a teacher-centered learning, when compared to other learning approaches. The high availability of PAWL increases the student-centricity of the learning approach, while the low availability of TFCL decreases its student-centricity, despite its high flexibility and interactivity, since the flexibility and interactivity are mostly controlled by the teacher, not by the student. Even though PAWL shows high availability compared to OTHI supported learning, its student-centricity is lower than OTHI supported learning due to its low flexibility, interactivity and motivation, on which student-centricity is also dependent. In addition, OTHI supported learning contains inquiry-based learning in which students are the center of learning and the role of the instructor is to assist the students in constructing their own knowledge.

The last row of Table 4.6 indicates the total results of the evaluation, which may represent the learning effectiveness of the learning approaches. TFCL with OTHI shows the highest effectiveness, while PAWL shows the lowest effectiveness. In addition, the results reveal TFCL is still a better learning approach than PAWL, and the two OTHI supported learning approaches are more effective than the others.

However, the total results may be changed if each attribute is given some weight to reflect its relative importance under a certain learning situation. The evaluation results of Table 4.6 can be gained only if every attribute has the same weight which is 1. Some courses may give a relatively high weight to the availability and low weight to other attributes so as to provide students with better learning environments for the courses. In real learning situations, the evaluation results may vary due to the consideration of additional evaluation attributes, as well as various attribute weights. For example, *collaborativity* may be added as one attribute to measure the effectiveness of the learning approaches for certain courses.

Although the results shown in Table 4.6 do not provide any empirical evidence regarding the effectiveness of OTHI, at least it can be said the results present the usefulness of OTHI in improving the learning effectiveness of other learning approaches.

Chapter 5

Conclusion

Chapter 5 concludes this research, summarizes its contributions, and presents possible future research directions.

5.1 Concluding Remarks

To address inquiry-based learning, we have developed a prototype of a WLSS called *OTHI*. We also have presented a treasure hunt model as a method of integrating the idea of IBL into the system. According to the treasure hunt model, the inquiry activity is considered the treasure hunt, and students learn a topic by developing an answer to a question regarding the topic through the treasure hunt.

The goal of this research was to design and implement a Web-based learning support system for IBL, which encourages students to actively take part in their learning by employing an online-learning game. Meanwhile, regarding the design of the system, this research was also required to find a solution to the integration of learning games into WLSS in a way that maximizes learning effectiveness.

Through this research, not only was a solution found, but also a Web-based learning support system was designed and its prototype was implemented with a solution for further research. As described in Chapter 2, the problem of Web-based learning was reviewed, and its background and available technologies were studied with several approaches to the problem. As presented in Chapter 3, the system's framework, the treasure hunt model, was defined, and its necessary components and functions for the system were discussed. The prototype of the system was implemented and demonstrated, and its usefulness was discussed, as addressed in Chapter 4.

5.2 Summary of Contributions

The following is the summary of contributions.

1. **Proposed a learning order relationship and its knowledge spaces for modelling an inquiry-based learning process.**
   The learning order relationship was conceptually and formally defined, including a learning order relation and term relation graph. The definition was extended to delineate the knowledge spaces of the learning order relationship by exploiting the knowledge space theory. The learning order relationship was applied to the modelling of an inquiry-based learning process.

2. **Identified IBL forms a treasure hunt.**
   The process of IBL was observed in a treasure hunt in which *treasure* is considered to be information, truth, or knowledge, and *hunt* implies inquiry. The process of the treasure hunt was reviewed in-depth. Phases, in the process of the treasure hunt, could, one by one, correspond to phases in the process of IBL. We found treasure hunt can represent IBL.

3. **Proposed a new Web-enabled IBL model with which an implementation of a WLSS complies.**
   The new Web-enabled IBL model, the treasure hunt model, was created by

formalizing the treasure hunt, which represents IBL. The components and functions of the model were devised. Furthermore, the student's learning state and knowledge construction process of the treasure hunt model were defined with the learning order relationship. The treasure hunt model was applied to the implementation of the prototype of a WLSS for IBL called *OTHI*.

4. **Employed online game technology to appropriately implement the idea of IBL into a WLSS.**
   The idea of IBL was appropriately implemented into *OTHI* by employing online game technology. An online treasure hunt game was developed based on the treasure hunt model, which contains the idea of IBL. *OTHI*, with the treasure hunt game, is capable of providing students with an IBL environment in which students are able to experience both the treasure hunt and IBL.

5. **Developed a prototype system with the treasure hunt model.**
   The prototype of *OTHI* was developed with several algorithms based on the treasure hunt model and showed how the system works for IBL. The evaluation of *OTHI* was performed by investigating the comparative advantages and disadvantages of each learning approach in previous studies.

5.3 Limitations and Future Research

The usefulness of *OTHI* was presented by the contrastive evaluation of *OTHI* supported learning against other learning approaches. However, there is no empirical evidence for the effectiveness of the system. Hence, an empirical study on *OTHI* will become a main area of future research. It requests to upgrade the prototype system into a production system and apply the system to a college course, in order to access how the system, with the model, actually works for learning. Through the empirical study, the strength of this approach is better understood.

The lack of development time narrowed the scope of features to be implemented for the prototype system. However, the following components and features should be upgraded or implemented for the production system. Some web pages of the prototype system are void of information. The empty pages need to be filled with useful information or links. As for the learning support subsystem (LSS) of *OTHI*, the following features are being considered for further implementation: 1) providing information about courses, topics, questions, sub-topics and clues; 2) offering a pretest page where students are able to see possible marks for their answer before giving the answer in the treasure hunt game; and 3) showing students' learning progress with their current knowledge states, as defined in Equation (3.16).

Another major improvement for the LSS will take place when replacing the role of the *Google Search* in the LSS with a new learning-oriented Web search engine. The indexing method of the new Web search engine is called *learning order indexing* and considers the learning order relationships between related learning objects in order to reflect user preference. This requires more research in developing a theoretical framework for the indexing method with the learning order relationship.

On the other hand, the main upgrade for the TSS of *OTHI* will allow the instructor to define and build *obstacle* stations into the treasure hunt game so monsters can provide players with simple surprise quizzes rather than attacking them in the game. As for the treasure hunt game, game objects will be capable of dealing with multiple topics, and appropriate articles, students post in the *blog*, will also be taken into account to award some experience points and golds in the game so as to further encourage students to post their ideas.

Finally, I wish to bring to light possible research areas where this preliminary study could be used to solve problems.

Appendix A

List of Symbols

$(\boldsymbol{T}, \boldsymbol{\sigma})$ surmise system

$\preceq$ learning order relation

$\boldsymbol{A_{\lambda}}$ series of actions

$\boldsymbol{ACT}$ set of actions

$\boldsymbol{AGT}$ set of agents

$\boldsymbol{CL}$ set of clues

$\boldsymbol{CMT}$ set of comments

$\boldsymbol{CO}$ set of conclusions

$\boldsymbol{EVT}$ set of events

$\boldsymbol{f_{EV}}$ evaluation function

$\boldsymbol{f_{HL}}$ help function

$\boldsymbol{f_{LE}}$ experience interpretation function

$\boldsymbol{f_{OA}}$	learning object allocation function
$\boldsymbol{f_{OB}}$	obstacle function
$\boldsymbol{f_{OT}}$	orientation function
$\boldsymbol{f_{SM}}$	similarity function
$\boldsymbol{f_{WI}}$	writing idea function
$\boldsymbol{GI}$	set of guides
$\boldsymbol{INF}$	set of information
$\boldsymbol{IS}$	idea structure
$\boldsymbol{IT}$	set of introductions
$\boldsymbol{K, K_\lambda}$	knowledge state
$\boldsymbol{K_n}$	new knowledge state
$\boldsymbol{\mathcal{K}}$	knowledge structure
$\boldsymbol{\mathcal{K}_R}$	knowledge structure of learning order relationship
$\boldsymbol{\mathcal{K}_S}$	knowledge space of learning order relationship
$\boldsymbol{L}$	learning topic
$\boldsymbol{LE}$	set of learning experiences
$\boldsymbol{LOG}$	set of logbooks
$\boldsymbol{LS}$	learning state structure
$\boldsymbol{OB}$	set of obstacles

$\boldsymbol{q}$ question

$\boldsymbol{QS}$ set of questions

$\boldsymbol{R}$ surmise relation

$\boldsymbol{R(f_{SM})}$ range of f_{SM}

$\boldsymbol{REL}$ set of relationship

$\boldsymbol{RS}$ set of resources

$\boldsymbol{RW}$ set of rewards

$\boldsymbol{S}$ structure of treasure hunt model

$\boldsymbol{s_\lambda}$ station

$\boldsymbol{SBJ}$ set of the subjects

$\boldsymbol{SD}$ set of students

$\boldsymbol{STA}$ set of stations

$\boldsymbol{SU}$ set of sub-topics

$\boldsymbol{T}$ set of learning objects

$\boldsymbol{t_0}$ course introduction

$\boldsymbol{t_\lambda}$ learning object and outer fringe of K_λ

$\boldsymbol{t_1, t_2}$ learning objects or terms

$\boldsymbol{T_K^I}$ inner fringe of K

$\boldsymbol{T_K^O}$ outer fringe of K

$\boldsymbol{TN}$ set of names of topics

$\boldsymbol{TP}$ set of learning topics

$\boldsymbol{TRE}$ set of treasures

$\boldsymbol{\lambda}$ sequence of stations

$\boldsymbol{\sigma}$ surmise function

Appendix B

Algorithms

```
/* Course Introduction Defining Algorithm                              */
Input: A course identification number $courseid$
Output: A course introduction object $\vec{t_0}$
1 create and initialize a learning object $\vec{t_0}$;
2 $\vec{t_0}$.course_id := $courseid$;
3 input a title $cname$ of the course; $\vec{t_0}$.course_title := $cname$;
4 input the course objectives $obj$; $\vec{t_0}$.course_objectives := $obj$;
5 input the course references $refs$; $\vec{t_0}$.course_references := $refs$;
```

Algorithm 1: Course Introduction Defining Algorithm

```
/* Knowledge Space and Outer Fringe Building Algorithm                 */
Data: A set $T$ of all learning objects of a course
Input: The course introduction object $\vec{t_0}$
Output: A knowledge space $\mathcal{K}_S$ on $T$ and an outer fringe $T_K^O$ for every
        knowledge state $K \in \mathcal{K}_S$
1 $\mathcal{K}_S, K, T_N := \emptyset$; $\vec{t} := \vec{t_0}$;
2 add $K$ to $\mathcal{K}_S$;    /* A knowledge space includes the empty set $\emptyset$.  */;
3 $K$ := Create_new_knowledge_state($K$,$\vec{t}$);
4 add $K$ to $\mathcal{K}_S$;
5 get next possible learning objects $T_N$ of learning object $\vec{t}$ from $T$;
6 $T_K^O := T_N$;
7 call Building_knowledge_space_and_outerfringe($\mathcal{K}_S$,$K$,$T_K^O$);
```

Algorithm 2: Knowledge Space and Outer Fringe Building Algorithm

```
/* Function Create_new_knowledge_state($K$,$\vec{t}$)                    */
Input: A knowledge state $K$ and a learning object $\vec{t}$
Output: A new knowledge state $K^{'}$
1 $K^{'} := \emptyset$;
2 add all elements of $K$ to $K^{'}$;
3 add $\vec{t}$ to $K^{'}$;
4 return $K^{'}$;
```

Algorithm 3: Function Create_new_knowledge_state(K,$\vec{t}$)

```
/* Building_knowledge_space_and_outerfringe($\mathcal{K}_S$,$K$,$T_K^O$)     */
/* $\mathcal{K}_S$ is a knowledge space, $K$ is a knowledge state.           */
/* $T_K^O$ is an outer fringe of $K$.                                          */
1 foreach learning object $\vec{t} \in T_K^O$ do
2     $K$ := Create_new_knowledge_state($K$,$\vec{t}$);
3     if $K \notin \mathcal{K}_S$ then add $K$ to $\mathcal{K}_S$;
4     if $T \nsubseteq K$ then
5         get next possible learning objects $T_N$ of learning object $\vec{t}$ from $T$;
6         $T_K^O := T_N$;
7         call Building_knowledge_space_and_outerfringe($\mathcal{K}_S$,$K$,$T_K^O$);
8     end
9 end
```

Algorithm 4: Procedure Building_knowledge_space_and_outerfringe($\mathcal{K}_S$,K,T_K^O)

```
/* Learning Environment Building Algorithm                                   */
Data: A set $T$ of all objects and a set $STA$ of all stations
Input: The course introduction object $\vec{t_0}$
Output: A knowledge space $\mathcal{K}_S$ on $T$, an outer fringe $T_K^O$ for every knowledge
        state $K \in \mathcal{K}_S$, and guides and treasure boxes having information and
        rewards to be delivered to students
1 $\mathcal{K}_S, K, T_N := \emptyset$; $\vec{t} := \vec{t_0}$;
2 add $K$ to $\mathcal{K}_S$;     /* A knowledge space includes the empty set $\emptyset$.  */;
3 $K$ := Create_new_knowledge_state($K$,$\vec{t}$);
4 add $K$ to $\mathcal{K}_S$;
5 get next possible learning objects $T_N$ of learning object $\vec{t}$ from $T$;
6 $T_K^O := T_N$;
7 question := null;
8 call Building_learning_environment($\mathcal{K}_S$,$K$,$T_K^O$,question);
```

Algorithm 5: Learning Environment Building Algorithm

```
/* Building_learning_environment($\mathcal{K}_S$,$K$,$T_K^O$,$question$)        */
/* Refer to Equation (3.10).                                                     */
/* $\mathcal{K}_S$ is a knowledge space, $K$ is a knowledge state, $T_K^O$       */
/* is an outer fringe of $K$, and $question$ contains a question.                */
foreach learning object $\vec{t} \in T_K^O$ do
    if $\vec{t}$ is an orientation object then
        repeat
            get a station $\vec{s} \in STA$;
        until $\vec{s}$ has a guide available to keep an information ;
        get an available guide $\vec{g} \in \vec{s}$.guides;
        $question$ := $\vec{t}$.question;
        $\vec{g}$.introduction := $\vec{t}$.introduction; $\vec{g}$.question := $question$;
    end
    else if $\vec{t}$ is a help object then
        repeat
            get a station $\vec{s} \in STA$;
        until $\vec{s}$ has a guide available to keep an information ;
        get an available guide $\vec{g} \in \vec{s}$.guides;
        $\vec{g}$.subtopic_description := $\vec{t}$.subtopic_description;
    end
    else if $\vec{t}$ is an evaluation object then
        repeat
            get a station $\vec{s} \in STA$;
        until $\vec{s}$ has a treasure box available to keep a treasure ;
        get an available treasure box $\vec{b} \in \vec{s}$.treasure_boxes;
        $\vec{b}$.question := $question$;
        $\vec{b}$.sample_answer := $\vec{t}$.sample_answer;
        $\vec{b}$.conclusion := $\vec{t}$.conclusion;
        get a reward $rw \in RW$; $\vec{b}$.reward := $rw$;
    end
    $K$ := Create_new_knowledge_state($K$,$\vec{t}$);
    if $K \notin \mathcal{K}_S$ then add $K$ to $\mathcal{K}_S$;
    if $T \nsubseteq K$ then
        get next possible learning objects $T_N$ of learning object $\vec{t}$ from $T$;
        $T_K^O$ := $T_N$;
        call Building_learning_environment($\mathcal{K}_S$,$K$,$T_K^O$,$question$);
    end
end
```

Algorithm 6: Procedure Building_learning_environment($\mathcal{K}_S$,K,T_K^O,$question$)

```
/* Learning Object Defining Algorithm                                  */
/* Refer to Equation (3.8) and Equation (3.9).                         */
Input: A course name, course
Output: A set $T$ of all learning objects of a course
$T := \emptyset$;
find a set $TP$ of all topics the course deals with;
foreach learning topic $L \in TP$ do
    /* Definition of an orientation object of $L$                      */
    create and initialize an object $\vec{t}$;
    input a topic title tname of $L$; $\vec{t}$.name := tname;
    input an introduction intro of $L$; $\vec{t}$.introduction := intro;
    input a question quest of $L$; $\vec{t}$.question := quest;
    $\vec{t}$.type := “an orientaion object”;
    add $\vec{t}$ to $T$;
    /* Definition of an evaluation object of $L$                       */
    create and initialize an object $\vec{t}$;
    $\vec{t}$.name := tname;
    input a conclusion con of $L$; $\vec{t}$.conclusion := con;
    display quest;
    input a sample answer ans for quest; $\vec{t}$.sample_answer := ans;
    input a clue clue, leading to this evaluation; $\vec{t}$.clue := clue;
    $\vec{t}$.type := “an evaluation object”;
    add $\vec{t}$ to $T$;
    /* Definitions of help objects of $L$                              */
    find all sub-topics of $L$;
    $i := 0$; $m :=$ the number of all sub-topics of $L$;
    repeat
        create and initialize an object $\vec{t}$;
        $\vec{t}$.topic_name := tname;
        select a sub-topic subtopic $\in L$;
        input a sub-topic title sname; $\vec{t}$.name := sname;
        input a description desc; $\vec{t}$.subtopic_description := desc;
        input a clue clue, leading to this sub-topic; $\vec{t}$.clue := clue;
        $\vec{t}$.type := “a help object”;
        add $\vec{t}$ to $T$; remove subtopic from $L$; $i := i + 1$;
    until $i \geq m$ ;
end
```

Algorithm 7: Learning Object Defining Algorithm

```
/* Refer to Equation (3.16), Equation (3.17), Equation (3.18)   */
Data: Outer fringes of all knowledge states $\in \mathcal{K}_S$ and a set $STA$ of all stations
Input: A course introduction object $\vec{t_0}$
Output: A knowledge state $K$ containing all learning objects $\in T$
$n := 0$; $clue, \vec{t}, \vec{s} :=$ null; $points := 0$; $RW, K :=$ the empty set;
display $\vec{t_0}$.course_title, $\vec{t_0}$.course_objectives and $\vec{t_0}$.course_references;
add $\vec{t_0}$ to $K$; $T_K^O :=$ Outerfringe($K$);
while $n <$ number of topics of the course do
    if $\vec{t} =$ null then select an object $\vec{t} \in T_K^O$;
    $\vec{s} :=$ Explore_stations_and_overcome_obstacles($\vec{t}$,$clue$,$RW$,$points$);
    if $\vec{t}$ is an orientation object then
        $\vec{o} :=$ Orientation($\vec{s}$,$\vec{t}$);
        if $\vec{o} \neq$ null then
            add $\vec{t}$ to $K$; $T_K^O :=$ Outerfringe($K$);
            display a list of all objects $\in T_K^O$; select an object $\vec{t}$ in the list;
            $clue :=$ Get_clue_for_next_station($\vec{o}.\vec{guide}$,$\vec{t}$);
        end
    end
    else if $\vec{t}$ is a help object then
        $\vec{h} :=$ Help($\vec{s}$,$\vec{t}$);
        if $\vec{h} \neq$ null then
            $K :=$ Knowledge_construction($K$,$\vec{o}$.question,$\vec{h}$,$\vec{t}$);
            $T_K^O :=$ Outerfringe($K$);
            display a list of all objects $\in T_K^O$; select an object $\vec{t}$ in the list;
            $clue :=$ Get_clue_for_next_station($\vec{h}.\vec{guide}$,$\vec{t}$);
        end
    end
    else if $\vec{t}$ is an evaluation object then
        if a treasure is found in a box $\vec{b} \in \vec{s}$.treasure_boxes then
            $reward :=$ Evaluation($\vec{b}$);
            if $reward \neq$ null then
                add $reward$ to $RW$;
                add $\vec{t}$ to $K$; $T_K^O :=$ Outerfringe($K$);
                $\vec{t}, \vec{o}, clue :=$ null; $n := n + 1$;
            end
        end
    end
end
```

Algorithm 8: Treasure Hunting Algorithm

```
/* Function Outerfringe($K$)                                         */
Data: Outer fringes of all knowledge states $\in \mathcal{K}_S$
Input: A knowledge state $K$
Output: An outer fringe $T_K^O$ of $K$
1 get an outer fringe $T_K^O$ of $K$ from data;
2 return $T_K^O$;
```

Algorithm 9: Function Outerfringe(K)

```
/* Function
   Explore_stations_and_overcome_obstacles($\vec{t}$,$clue$,$RW$,$points$)     */
/* Refer to Equation (3.15).                                          */
Input: A learning object $\vec{t}$, a clue $clue$, a set of obtained rewards $RW$ and
       experience points $points$
Result: Accumulated $points$ and a station $\vec{s} \in STA$.
1 repeat
2     moves to a station $\vec{s} \in STA$ using $clue$;
3     if $\vec{s}$ is an obstacle station then
4         $obstacle := \vec{s}$.obstacle;
5         get experience points $exp$ by defeating $obstacle$ with available tools and
          equipments $\in RW$;
6         $points := points + exp$;
7     end
8 until $\vec{s}$ is the orientation, help or evaluation station of $\vec{t}$ ;
9 return $\vec{s}$;
```

Algorithm 10: Function Explore_stations_and_overcome_obstacles($\vec{t}$,$clue$,RW,$points$)

```
/* Function Get_clue_for_next_station($\vec{g}$,$\vec{t}$)                          */
Input: A guide $\vec{g}$ and an object $\vec{t}$
Output: A clue $clue$
1 $\vec{g}$.clue := $\vec{t}$.clue;
2 $clue$ := $\vec{g}$.clue;
3 display $\vec{g}$.clue;
4 return $clue$;
```

Algorithm 11: Function Get_clue_for_next_station($\vec{g}$,$\vec{t}$)

```
/* Function Orientation($\vec{s}$,$\vec{t}$)                                  */
/* Refer to Equation (3.11).                                                   */
Input: A station $\vec{s}$ and an object $\vec{t}$
Output: An orientation information $\vec{o}$
$\vec{o}$ := null;
get an attention from a guide $\vec{g} \in \vec{s}$.guides by saying hello;
ask $\vec{g}$ for a help about $\vec{t}$;
if $\vec{g}$ has the information about $\vec{t}$ then
    display $\vec{g}$.introduction;
    if student wants to learn this topic then
        $\vec{o}$.introduction := $\vec{g}$.introduction;
        $\vec{o}$.question := $\vec{g}$.question;
        $\vec{o}.\vec{guide}$ := $\vec{g}$;
        display $\vec{g}$.question;
        post the introduction and question to blog;
    else
        display "Bye";
    end
else
    display "No information";
end
return $\vec{o}$;
```

Algorithm 12: Function Orientation($\vec{s}$,$\vec{t}$)

```
/* Function Evaluation($\vec{b}$)                                        */
/* Refer to Equation (3.14).                                              */
Input: A treasure box $\vec{b}$
Output: A reward $rw$ for the answer
1  $rw$ := null;
2  display $\vec{b}$.question;
3  input a student answer $a^{'}$;
4  $a$ := $\vec{b}$.sample_answer;
5  $marks$ := Similarity($\vec{b}$.question,$a$,$a^{'}$) * 100;    /* Refer to Equation (3.13)
   */;
6  if $marks > 50$ then
7      $rw$ := $\vec{b}$.reward;
8      display $\vec{b}$.conclusion;
9      post the conclusion to $blog$;
10 end
11 return $rw$;
```

Algorithm 13: Function Evaluation($\vec{b}$)

```
/* Function Help($\vec{s}$,$\vec{t}$)                                     */
/* Refer to Equation (3.12).                                              */
Input: A station $\vec{s}$ and an object $\vec{t}$
Output: A help information $\vec{h}$
1  $\vec{h}$ := null;
2  get an attention from a guide $\vec{g} \in \vec{s}$.guides by saying hello;
3  ask $\vec{g}$ for a help about $\vec{t}$;
4  if $\vec{g}$ has the information about $\vec{t}$ then
5      $\vec{h}$.subtopic_description := $\vec{g}$.subtopic_description; $\vec{h}.\vec{guide}$ := $\vec{g}$;
6      display $\vec{g}$.subtopic_description;
7      post the sub-topic description to $blog$;
8  else
9      display “No information”;
10 end
11 return $\vec{h}$;
```

Algorithm 14: Function Help($\vec{s}$,$\vec{t}$)

```
/* Function Knowledge_construction($K$,$question$,$\vec{h}$,$\vec{t}$)        */
/* Refer to Equation (3.20).                                                   */
Data: Resources $RS$
Input: A knowledge state $K$, a question $question$, help information $\vec{h}$, and a
       learning object $\vec{t}$
Output: A new knowledge state $K_n$
$K_n := \emptyset$;
add all elements of $K$ to $K_n$;
initialize an idea structure $\vec{is}$          /* Refer to Equation (3.19).  */;
$\vec{is}$.sequence := the number of records in $blog + 1$;
$\vec{is}$.question := $question$;
display $question$;
$subtopic\_desc := \vec{h}$.subtopic_description;
display $subtopic\_desc$;
analyze $subtopic\_desc$ with regard to $question$;
input a subject $sbj$ using $\vec{t}$.name;
$\vec{is}$.subject := $sbj$;
input a comment $cmt$ using $subtopic\_desc$;
$\vec{is}$.comment := $cmt$;
$\vec{is}$.relationship := “Sub Topic”;
while need more information about cmt do
    retrieve information $inf$ about $cmt$ from $RS$;
    analyze $inf$ with regard to $question$;
    update the comment $cmt$ using $inf$;
    $\vec{is}$.comment := $cmt$;
end
post $\vec{is}$ to $blog$;
add $\vec{t}$ to $K_n$;
return $K_n$;
```

Algorithm 15: Function Knowledge_construction(K,$question$,$\vec{h}$,$\vec{t}$)

Appendix C

XML Files

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- <!DOCTYPE places SYSTEM "places.dtd"> -->
<places>
<!-- Should also define speed to make it talk. It is used to calculate the talking speed  -->
 <place name="0_network_city" level="0" x="500064" y="500000" file="Level 0/network/city.tmx">
     <npc x="26" y="21" name="Alice" imgRef="woman_000_npc" speed="0.1" direction="WEST">
         <path sx="26" sy="21" dx="26" dy="25"/>
         <path sx="26" sy="25" dx="26" dy="21"/>
     </npc>
   <portal x="42" y="37" ref="tavern_entrance">
     <destination place="int_network_tavern_0" ref="entrance"/>
   </portal>
  <portal x="59" y="37" ref="house_exit_1">
   <implementation class="ca.uregina.thg.server.entities.portal.OneWayPortalDestination"/>
  </portal>
  <portal x="53" y="37" ref="temple_entrance">
   <destination place="int_network_temple" ref="entrance_center_right"/>
  </portal>
   <!--
 Deleted some definitions to be published with the thesis.
   -->
   <place name="int_network_library" file="interiors/network/library.tmx">
     <npc x="28" y="17" name="Monogenes" imgRef="oldmannpc" speed="0.1" direction="WEST"/>
    <monster name="rat" x="28" y="20" direction="SOUTH"/>
    <monster name="rat" x="20" y="25" direction="NORTH"/>
    <food name="cheese" x="28" y="28"/>
    <food name="cheese" x="18" y="20"/>
    <portal x="8" y="30" ref="entrance_left">
     <destination place="0_network_city" ref="library_entrance_left"/>
    </portal>
    <portal x="21" y="30" ref="entrance_right">
     <destination place="0_network_city" ref="library_entrance_right"/>
    </portal>
   </place>
   <!--
 Deleted some definitions to be published with the thesis.
   -->
   <place name="int_network_townhall" file="interiors/network/townhall.tmx">
    <npc name="Boy" x="12" y="18" class="ca.uregina.thg.server.entities.npcs.network.townhall.BoyNPC" />
    <npc name="Mayor" x="13" y="2"  class="ca.uregina.thg.server.entities.npcs.network.townhall.MayorNPC" />
    <treasure name="Box 9" x="24" y="38"/>
    <treasure name="Box 10" x="22" y="38"/>
    <treasure name="Box 11" x="20" y="38"/>
    <treasure name="Box 12" x="18" y="38"/>
    <portal x="14" y="46" ref="entrance_left">
     <destination place="0_network_city" ref="townhall_entrance_left"/>
    </portal>
    <portal x="15" y="46" ref="entrance">
     <destination place="0_network_city" ref="townhall_entrance"/>
    </portal>
    <portal x="16" y="46" ref="entrance_right">
     <destination place="0_network_city" ref="townhall_entrance_right"/>
    </portal>
    <portal x="30" y="5" ref="storage_entrance">
     <destination place="int_townhall_storage" ref="townhall_entrance"/>
    </portal>
   </place>
   <place name="int_townhall_storage" file="interiors/network/townhall_storage.tmx">
    <monster name="rat" x="6" y="3" direction="SOUTH"/>
    <monster name="rat" x="13" y="5" direction="NORTH"/>
    <monster name="rat" x="13" y="9" direction="EAST"/>
    <monster name="rat" x="15" y="7" direction="WEST"/>
    <food name="cheese" x="4" y="7"/>
```

```xml
      <food name="cheese" x="6" y="10"/>
      <food name="cheese" x="15" y="12"/>
      <treasure name="Box 13" x="2" y="2"/>
      <treasure name="Box 14" x="4" y="2"/>
      <treasure name="Box 15" x="6" y="2"/>
      <treasure name="Box 16" x="8" y="2"/>
      <treasure name="Box 17" x="10" y="2"/>
      <treasure name="Box 18" x="12" y="2"/>
      <portal x="1" y="26" ref="townhall_entrance">
          <destination place="int_network_townhall" ref="
              storage_entrance"/>
      </portal>
    </place>
    <!--
 Deleted some definitions to be published with the thesis.
    -->
 </place>
</places>
```

Listing C.1: Place XML

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<introduction>
<id>CS335</id>
<title>Data Communications and Network</title>
<objective>Course Objective</objective>
<references>Course References</references>
</introduction>
```

Listing C.2: Course Introduction XML

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<orientation>
<topic title="Data Link Layer">
<introduction>Data link layer supervises the flow of information
   between adjacent network nodes. It uses error detection or
   correction techniques to ensure that a transmission contains no
   errors.</introduction>
<question>Describe what the data link layer works for networking.</
   question>
</topic>
</orientation>
```

Listing C.3: Orientation XML

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<evaluation>
<topic title="Data Link Layer">
```

```
<sample_answer>The data link layer is layer two of the seven-layer
    OSI model as well as of the five-layer TCP/IP reference model. It
     receives services from physical layer and provides services to
    network layer. The data link layer is responsible for carrying a
    packet from one node to another and has only a local
    responsibility. Its main functions are error control and flow
    control.</sample_answer>
<conclusion>The task of the data link layer is to convert noisy
    lines into communication channels free of transmission errors for
     use by the network layer.</conclusion>
<clue>The treasure of the data link layer is in a storage of the
    town hall.</clue>
</topic>
</evaluation>
```

Listing C.4: Evaluation XML

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<sub-topics>
<sub-topic main-title="Data Link Layer" sub-title="DLL Duties">
<description>The duties of the data link layer include packetizing
    and framing, addressing error control, and flow control.</
    description>
<clue>A boy is working in a town hall.</clue>
</sub-topic>
<sub-topic main-title="Data Link Layer" sub-title="Error detection">
<description>The data link layer performs the error check using the
    Frame Check Sequence (FCS) in the trailer and discards the frame
    if an error is detected. The corrupted message frame may need to
    be retransmitted under control of an upper layer.</description>
<clue>A woman is waiting for you in a city.</clue>
</sub-topic>
<sub-topic main-title="Data Link Layer" sub-title="Flow control">
<description>The data link layer defines the data values used in the
     flow control signaling between two transmitting hosts. There are
     two types of flow control implemented in data communications
    such as software flow control and hardware flow control.</
    description>
<clue>An old man is sitting in a library.</clue>
</sub-topic>
</sub-topics>
```

Listing C.5: Sub-topics XML

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<stations>
<station name="Orientation" place="int_network_townhall"
    place_nick_name="Town Hall" topic="Data Link Layer">
```

```xml
<guide>Mayor</guide>
<next_quests>DLL Duties</next_quests>
</station>
<station name="DLL Duties" place="int_network_townhall"
    place_nick_name="Town Hall" topic="Data Link Layer">
<guide>Boy</guide>
<next_quests>Error detection</next_quests>
<clue>A boy is working in a town hall.</clue>
</station>
<station name="Error detection" place="0_network_city"
    place_nick_name="Network City" topic="Data Link Layer">
<guide>Alice</guide>
<next_quests>Flow control</next_quests>
<clue>A woman is waiting for you in a city.</clue>
</station>
<station name="Flow control" place="int_network_library"
    place_nick_name="Network Library" topic="Data Link Layer">
<guide>Monogenes</guide>
<next_quests>Evaluation</next_quests>
<clue>An old man is sitting in a library.</clue>
</station>
<station name="Evaluation" place="int_townhall_storage"
    place_nick_name="Town Hall Storage" topic="Data Link Layer">
<treasure_box>Box 13</treasure_box>
<clue>The treasure of the data link layer is in a storage of the
    town hall.</clue>
</station>
</stations>
```

Listing C.6: Stations XML

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<guides>
<guide name="Mayor" nick_name="DLL Introduction" place="
    int_network_townhall" topic="Data Link Layer">
<talk>I want to introduce you the data link layer. The data link
    layer supervises the flow of information between adjacent network
      nodes. It uses error detection or correction techniques to
    ensure that a transmission contains no errors.</talk>
<question>You need to describe what the data link layer works for
    networking in order to complete this quest.</question>
<clue/>
</guide>
<guide name="Boy" nick_name="DLL Duties" place="int_network_townhall
    " topic="Data Link Layer">
<talk>The duties of the data link lay include packetizing and
    framing, addressing error control, and flow control.</talk>
<question/>
```

```
<clue/>
</guide>
<guide name="Alice" nick_name="Error Detection" place="0
    _network_city" topic="Data Link Layer">
<talk>The data link layer performs the error check using the Frame
    Check Sequence (FCS) in the trailer and discards the frame if an
    error is detected. The corrupted message frame may need to be
    retransmitted under control of an upper layer.</talk>
<question/>
<clue/>
</guide>
<guide name="Monogenes" nick_name="Flow Control" place="
    int_network_library" topic="Data Link Layer">
<talk>The data link layer defines the data values used in the flow
    control signaling between two transmitting hosts. There are two
    types of flow control implemented in data communications such as
    software flow control and hardware flow control.</talk>
<question/>
<clue/>
</guide>
</guides>
```

Listing C.7: Guides XML

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<treasures>
<treasure name="Box 13" place="int_townhall_storage" topic="Data
    Link Layer">
<question>Describe what the data link layer works for networking.</
    question>
<sample_answer>The data link layer is layer two of the seven-layer
    OSI model as well as of the five-layer TCP/IP reference model. It
     receives services from physical layer and provides services to
    network layer. The data link layer is responsible for carrying a
    packet from one node to another and has only a local
    responsibility. Its main functions are error control and flow
    control.</sample_answer>
<conclusion>The task of the data link layer is to convert noisy
    lines into communication channels free of transmission errors for
     use by the network layer.</conclusion>
<golds>1000</golds>
<experience_point>500</experience_point>
<tool>Pick</tool>
<armor>Leather scale armor</armor>
<weapon>Sword</weapon>
</treasure>
</treasures>
```

Listing C.8: Treasures XML

```
<?xml version="1.0" encoding="UTF-8"?>
<jnlp spec="1.0+" codebase="http://localhost/thg" href="thg.jnlp">
    <information>
        <title>Treasure Hunt Game</title>
        <vendor>OTHI, Computer Science, University of Regina</vendor
            >
 <description>Treasure Hunt Game</description>
        <description kind="short">Treasure Hunt Game is a
            multiplayer online learning game.</description>
        <homepage href="http://localhost/"/>
 <icon href="default.jpg"/>
        <icon kind="splash" href="othi_long_logo_72x72.png"/>
 <offline-allowed/>
    </information>
<!-- <update check="always" policy="prompt-update"/> -->
 <update check="always" policy="always"/>
    <security>
        <all-permissions/>
    </security>
    <resources>
 <j2se version="1.6+"/>
 <jar href="thgclient.jar" main="true" download="eager"/>
 <jar href="sgs_client.jar" download="eager"/>
 <jar href="sgs_shared.jar" download="eager"/>
 <jar href="mina_core.jar" download="eager"/>
 <jar href="jogg.jar" download="eager"/>
 <jar href="jorbis.jar" download="eager"/>
 <jar href="slf4j_api.jar" download="eager"/>
 <jar href="slf4j_jdk14.jar" download="eager"/>
 <jar href="lwjgl.jar" download="eager"/>
 <jar href="jinput.jar" download="eager"/>
 <jar href="slick.jar" download="eager"/>
    </resources>
    <resources os="Windows">
  <j2se version="1.6+"/>
        <nativelib href="natives_win32.jar" download="eager"/>
    </resources>
    <resources os="Linux">
  <j2se version="1.6+"/>
        <nativelib href="natives_linux.jar" download="eager"/>
    </resources>
    <resources os="Mac OS X">
  <j2se version="1.6+"/>
        <nativelib href="natives_mac.jar" download="eager"/>
    </resources>
    <application-desc main-class="ca.uregina.thg.client.
        TreasureHuntGame">
<!--${JNLP.APPLICATION.ARGS}-->
    </application-desc>
</jnlp>
```

Listing C.9: JNLP Definition for Treasure Hunt Game

Appendix D

PHP Programs Added To Joomla

```
<?php // no direct access
defined('_JEXEC') or die('Restricted access');

define("BROWSE_MODE", "0");
define("EDIT_MODE", "1");
?>

<?php
if ($this->blog_mode == BROWSE_MODE) {
 header("Location: ".$this->blogURL);
}
?>
<html>
<body onLoad="document.forms['othi'].submit()">
<form action="<?php echo $this->blogURL; ?>?flavor=admin&plugins=
    edit-blog-entries&action=new-blog-entry" method="post" name="othi
    ">
<input type="hidden" name="username" value="<?php echo $this->
    username ?>" />
<input type="hidden" name="password" value="<?php echo $this->
    password ?>" />
</form>
</body>
</html>
```

Listing D.1: Default.php

```
<?php

// No direct access

defined( '_JEXEC' ) or die( 'Restricted access' );

jimport('joomla.application.component.controller');
```

```


class OthiController extends JController
{
    /**
     * Method to display the view
     *
     * @access    public
     */
    function display()
    {
        parent::display();
    }
}
```

Listing D.2: Controller.php

```
<?php
/**
 * @package    Joomla.Tutorials
 * @subpackage Components
 * @link http://docs.joomla.org/Developing_a_Model-View-
     Controller_Component_-_Part_1
 * @license    GNU/GPL
*/

// no direct access

defined( '_JEXEC' ) or die( 'Restricted access' );

jimport( 'joomla.application.component.view');


class OthiViewOthi extends JView
{
    function display($tpl = null)
    {
        $model =& $this->getModel();
        $blogURL = $model->getBlogURL();
        $this->assignRef( 'blogURL',  $blogURL );

  $params = &JComponentHelper::getParams( 'com_othi' );
  $blog_mode = $params->get('blog_mode');

       $this->assignRef('blog_mode', $blog_mode);

   $user =& JFactory::getUser();
  $username = $user->username;
  $password = $user->password;

     $this->assignRef('username', $username);
     $this->assignRef('password', $password);

         parent::display($tpl);
    }
}
```

Listing D.3: View.html.php

```
<?php
// No direct access
defined( '_JEXEC' ) or die( 'Restricted access' );

// Require the base controller

require_once( JPATH_COMPONENT.DS.'controller.php' );

// Require specific controller if requested
if($controller = JRequest::getWord('controller')) {
    $path = JPATH_COMPONENT.DS.'controllers'.DS.$controller.'.php';
    if (file_exists($path)) {
        require_once $path;
    } else {
        $controller = '';
    }
}

// Create the controller
$classname    = 'OthiController'.$controller;
$controller   = new $classname( );

// Perform the Request task
$controller->execute( JRequest::getVar( 'task' ) );

// Redirect if set by the controller
$controller->redirect();
```

Listing D.4: Othi.php

```
<?php
/**
 * Hello Model for Hello World Component
 *
 * @package    Joomla.Tutorials
 * @subpackage Components
 * @link http://docs.joomla.org/Developing_a_Model-View-
     Controller_Component_-_Part_2
 * @license    GNU/GPL
 */

// No direct access

defined( '_JEXEC' ) or die( 'Restricted access' );

jimport( 'joomla.application.component.model' );

/**
 * Hello Model
 *
 * @package    Joomla.Tutorials
 * @subpackage Components
 */
class OthiModelOthi extends JModel
{

 function getBlogURL()
 {
  $user =& JFactory::getUser();
  $username = $user->username;

  $db =& JFactory::getDBO();

  $query = " SELECT c.property_value, d.name FROM jos_othi_users AS
     a, jos_othi_courses AS b, blog_properties AS c, blog_category
     AS d ".
       " WHERE a.username = '".$username."' and a.blog_category_id
          = d.category_id and a.course_id = b.course_id and ".
       " b.blog_id = c.blog_id and c.property_name = 'blog-url' ";

     $db->setQuery( $query );
     $row= $db->loadRow();

     return $row['0'].$row['1'];
 }

}
```

Listing D.5: Othi.php in models

Appendix E

Java Programs of Treasure Hunt Game

```
package ca.uregina.thg.client;

import ca.uregina.thg.common.GameDefault;
import org.newdawn.slick.AppGameContainer;
import org.newdawn.slick.GameContainer;
import org.newdawn.slick.SlickException;
import org.newdawn.slick.state.StateBasedGame;

/**
 * Clinet main program
 * @author Dong Won Kim
 */
public class TreasureHuntGame extends StateBasedGame {
    public static String GAMEHOST = "localhost";
    public static String GAMEPORT = "13134";

    public TreasureHuntGame() {
        super("OTHI - Online Treasure Hunt for Inquiry-based
           learning!");
    }

    public TreasureHuntGame(String arg0) {
        super(arg0);
    }

    @Override
    public void initStatesList(GameContainer container) {
        addState(new THGkeeper());
        addState(new THGground());
    }

    public static void main(String[] args) {
        if (args.length > 0) {
                GAMEHOST = args[0];
```

```
            if (args.length > 1) {
                GAMEPORT = args[1];
            }
        }
        try {
            AppGameContainer container = new AppGameContainer(new
                TreasureHuntGame());

            container.setDisplayMode(GameDefault.SCREEN_WIDTH,
                GameDefault.SCREEN_HEIGHT, false);
            container.start();
        } catch (SlickException e){
            e.printStackTrace();
        }
    }
}
```

Listing E.1: Client main program

```
package ca.uregina.thg.server;

import java.io.Serializable;
import java.io.IOException;
import java.util.Properties;
import java.util.Enumeration;
import java.util.logging.Level;
import java.util.logging.Logger;

import com.sun.sgs.app.AppContext;
import com.sun.sgs.app.AppListener;
import com.sun.sgs.app.ClientSession;
import com.sun.sgs.app.ClientSessionListener;
import com.sun.sgs.app.Channel;
import com.sun.sgs.app.ChannelManager;
import com.sun.sgs.app.Delivery;
import com.sun.sgs.app.ManagedReference;
import com.sun.sgs.app.DataManager;
import com.sun.sgs.app.NameNotBoundException;

import ca.uregina.thg.server.config.*;

import ca.uregina.thg.common.Commands;
import ca.uregina.thg.common.GameDefault;
/**
 * Loading properties of game objects and verifying player
 * @author Dong Won Kim
 */
public class THGServer implements AppListener, Serializable {

        private static final Logger logger = Logger.getLogger(THGServer.class.getName());

        private static final long serialVersionUID = 1L;

        private static final String ENTRY_PLACE = "int_network_townhall";
        private static final float ENTRY_X = 15;
        private static final float ENTRY_Y = 19;

        /** The name of the first channel: {@value #CHANNEL_1_NAME} */
        public static final String CHANNEL_1_NAME = "Foo";
        /** The name of the second channel: {@value #CHANNEL_2_NAME} */
        public static final String CHANNEL_2_NAME = "Bar";
        /**
        * The first {@link Channel}.
        * (The second channel is looked up by name only.)
        */
        private ManagedReference<Channel> channel1 = null;

        private int maxPlayerId = Integer.MIN_VALUE;

        private ManagedReference thoWorldRef = null;

@Override
        public void initialize(Properties props) {

            ChannelManager channelManager = AppContext.getChannelManager();
            // Create and keep a reference to the first channel.
            Channel c1 = channelManager.createChannel(CHANNEL_1_NAME, null, Delivery.RELIABLE);

            channel1 = AppContext.getDataManager().createReference(c1);

            // We don't keep the second channel object around, to demonstrate
            // looking it up by name when needed.
            channelManager.createChannel(CHANNEL_2_NAME, null, Delivery.RELIABLE);

            THGWorld thoWorld = new THGWorld();

            DataManager dm = AppContext.getDataManager();
            thoWorldRef = dm.createReference(thoWorld);
            dm.setBinding(GameDefault.THOWORLD, thoWorld);

            String appRoot = props.getProperty("com.sun.sgs.app.root
                ");

            ConfigDefault.setConfigDir(appRoot + "/config/");

            try {
                LevelDefinition.loadConfiguredLevel();

                MonsterDefinition.loadConfiguredMonsters();

                FoodDefinition.loadConfiguredFoods();

                StationDefinition.loadConfiguredStations();

                PlaceDefinition.loadConfiguredPlaces();

            } catch (IOException e) {
                logger.log(Level.SEVERE, null, e);
            }

            if (maxPlayerId < 0) maxPlayerId = 0;

            thoWorld.worldStart();
}

        private void printProperties(Properties arg0) {
            String app_root = arg0.getProperty("com.sun.sgs.app.root
                ");
            System.out.println("com.sun.sgs.app.root : " + app_root)
                ;

            Enumeration e = arg0.propertyNames();
            while (e.hasMoreElements()) {
                Object o = e.nextElement();
                System.out.println("property : " + o.toString());
            }
        }

@Override
        public ClientSessionListener loggedIn(ClientSession arg0) {

            String name = arg0.getName();
            Player player;

            DataManager dm = AppContext.getDataManager();
            try {
                    player = (Player) dm.getBinding(GameDefault.
                       USERPREFIX + name);
                    if (player.isLoggedIn()) return null;
            } catch (NameNotBoundException ex) {
                    player = new Player(name);
                    dm.setBinding(GameDefault.USERPREFIX + name,
                       player);
                    ++maxPlayerId;
            }

            player.setLoggedIn(true);
            PlayerListener pl = new PlayerListener(player.getName(),
                 arg0);

            dm.markForUpdate(player);
            player.setPlayerListener(pl);
            setupPlayer(player);

            return pl;
}

private void setupPlayer(Player player) {
            if (player.getId() == Integer.MIN_VALUE) player.setId(
               maxPlayerId);

            if (player.getGameBoard() == null) {
                DataManager dm = AppContext.getDataManager();
                GameBoard gameBoard = (GameBoard) dm.getBinding(
                   GameDefault.GAMEBOARD + ENTRY_PLACE);
                player.setGameBoard(gameBoard);
            }

            if (player.getPlace() == null) {
                player.locatePlace(ENTRY_PLACE, ENTRY_X, ENTRY_Y);
            }

            sendPlayerInitialInfo(player);
            logger.info("Complete setting up player " + player.getId
               () + " session name : " + player.getPlayerListener().
               getSession().getName());
}

    protected void sendPlayerInitialInfo(Player player)
    {
        DataManager dm = AppContext.getDataManager();
        Competence pCompetence= (Competence) dm.getBinding(
           GameDefault.PLAYER_COMPETENCE + player.getName());
```

```
            ArmedArmor pArmor = (ArmedArmor) dm.getBinding(GameDefault.
                PLAYER_ARMOR + player.getName());

            GameLevel gameLevel = pCompetence.getLevelEntity();
            int maxHp = gameLevel.getHp();
            int maxMp = gameLevel.getMp();
            int maxExp = gameLevel.getExp();
            player.getPlayerListener().sendMove(Commands.
                initializePlayerCommand(
                    player.getId(),
                    player.getPlace().getId(),
                    player.getPlace().getMapFileRef(),
                    pCompetence.getGameLevel(), pCompetence.getHP(),
                        maxHp,
                    pCompetence.getMP(), maxMp,
                    pCompetence.getMyExp(), maxExp,
                    pCompetence.getMyMoney(),
                    player.getInventory().getDialogueHistory().toArray(
                        new String[0]), pArmor.getOutfitCode())
            );
        }
}
```

Listing E.2: Server main program

```
package ca.uregina.thg.server.authenticator;

import java.security.MessageDigest;
import java.security.NoSuchAlgorithmException;
import java.sql.Connection;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.Properties;

import java.util.logging.Level;
import java.util.logging.Logger;
import javax.security.auth.login.CredentialException;
import javax.security.auth.login.LoginException;

import com.sun.sgs.auth.Identity;
import com.sun.sgs.auth.IdentityAuthenticator;
import com.sun.sgs.auth.IdentityCredentials;
import com.sun.sgs.impl.auth.NamePasswordCredentials;

/**
 * This authenticator will connect to a specific table in the
 * MySQL database and try to retrieve a password field from a row
 * in that table. Be sure to set the constants at the start
 * of the source code so that the Database, Table, and Column
 * Names match the ones in your MySQL database.
 *
 * @author Chuck Liddell
 * @author Dong Won Kim
 */
public class THGAuthenticator implements IdentityAuthenticator {

    private static final Logger logger = Logger.getLogger(
        THGAuthenticator.class.getName());

   /**
   * @param prop Reference properties (unused in this implementation)
   */
    public THGAuthenticator(Properties prop){
     logger.info("Custom Authenticator instantiated.");
    }

    @Override
    public Identity authenticateIdentity(IdentityCredentials
        credentials) throws LoginException
    {
     if (! (credentials instanceof NamePasswordCredentials))
            throw new CredentialException("Unsupported credentials")
                ;
        NamePasswordCredentials npc = (NamePasswordCredentials)
            credentials;

        // Pull the data that we need from the credentials
        String userName = npc.getName().toLowerCase(); // don't
            worry about case
        String password = new String(npc.getPassword());

        // Call a method that will check the MySQL database for this
            user
        String matchPassword = getPasswordForUser(userName);

        if (matchPassword == null){ // This user was not found in
            the database
            throw new CredentialException("User does not exist");
        }
        else {
            try {
                String[] part = matchPassword.split(":");
                String salt = part[1];

                MessageDigest m = MessageDigest.getInstance("MD5");
                byte  b[] = m.digest(new String(password + salt).
                    getBytes());
                java.math.BigInteger bi = new java.math.BigInteger
                    (1, b);
                String encryptedPasswd = bi.toString(16);
                while (encryptedPasswd.length() < 32)
                encryptedPasswd = "0" + encryptedPasswd;

                encryptedPasswd = encryptedPasswd + ":" + salt;

                if (!matchPassword.equals(encryptedPasswd)){ // User
                     found, but wrong password
                    throw new CredentialException("Invalid password"
                        );
                }
            } catch (NoSuchAlgorithmException ex) {
                logger.log(Level.SEVERE, null, ex);
            }
        }

        // IdentityImpl is an extremely simple class that implements
             the Identity interface.
        // If we reach this point in the method code we are
            acknowledging that
        // the user credentials we were given are acceptable.
        //return new IdentityImpl(userName);
        return new THGIdentity(userName, password);
    }

    /**
     * Searches a MySQL database for a record that matches the given
         username.
     * @param userName The username to search for in the database
     * @return The matching password for the given username, or null
         if no valid record was found.
     */
    private String getPasswordForUser(String userName) {
        String password = null; // value we will return at the end
            of the method
     try {
      // Attempt to connect to the database
            Connection conn = DataBase.getConnection();

            // Build an SQL query that will locate the correct
                username / password record
            String query = "SELECT " + DataBase.PASSWORD_COLUMN_NAME
                + " FROM " + DataBase.JOS_USER_TABLE_NAME +
                " WHERE " + DataBase.JOS_USERNAME_COLUMN_NAME + " =
                    ?";
            PreparedStatement stmt = conn.prepareStatement( query );
            stmt.setString(1, userName);
            logger.info("Query: " + stmt.toString());

            // The time statements let you know how long your MySQL
                queries are taking
            long startTime = System.nanoTime();

            // This line applies your SQL query to the database
            // The database returns the results as a ResultSet
            ResultSet results = stmt.executeQuery();

            long estimatedTime = System.nanoTime() - startTime;
            logger.info("Execution time: " + estimatedTime / Math.
                pow(10, 6) + " ms" );

            // Check to see if the ResultSet has any entries
            // If it does, take the first one and grab the password
                from the 'Password' database column
            if( results.next() ) { // results.next() returns true if
                 there is at least one result
                password = results.getString( DataBase.
                    PASSWORD_COLUMN_NAME );
            }

            stmt.close();
        } catch (com.mysql.jdbc.exceptions.jdbc4.
            CommunicationsException e) {
                logger.log(Level.SEVERE, "MY SQL NOT STARTED!", e);
        } catch (SQLException e) {
                logger.log(Level.SEVERE, "SQL ERROR!", e);
        }
        // Return the password, or null if no records were returned
            by the database
        return password;
    }

    @Override
    public String[] getSupportedCredentialTypes() {
        return new String[] {"NameAndPasswordCredentials"};
    }
}
```

Listing E.3: Authentication server program

```
package ca.uregina.thg.server.authenticator;
```

```java

import java.sql.Connection;
import java.sql.Driver;
import java.sql.DriverManager;
import java.sql.SQLException;
import java.util.logging.Logger;
import java.util.logging.Level;

/**
 * Database definition
 * @author Dong Won Kim
 */

public class DataBase {

    private static final Logger logger = Logger.getLogger(DataBase.class.getName());

    //These constants are used to connect to the MySQL database
    private static final String SQL_HOST_NAME      = "localhost";
    private static final String SQL_DATABASE_NAME  = "wss";
    private static final String SQL_USERNAME       = "wss";
    private static final String SQL_PASSWORD       = "Wlss@003";
    public static final String JOS_USER_TABLE_NAME = "jos_users";
    public static final String JOS_USERNAME_COLUMN_NAME = "username";
    public static final String PASSWORD_COLUMN_NAME = "password";

    //OTHI Tables
    public static final String OTHI_USER_TABLE_NAME = "jos_othi_users";
    public static final String COURSE_TABLE_NAME = "jos_othi_courses";
    public static final String OTHI_USER_COLUMN_NAME = "username";
    public static final String COURSE_ID_COLUMN_NAME = "course_id";
    public static final String COURSE_NAME_COLUMN_NAME = "course_name";
    public static final String BLOG_CATEGORY_ID_COLUMN_NAME = "blog_category_id";
    public static final String BLOG_ID_COLUMN_NAME = "blog_id";

    //Blog Tables;
    public static final String BLOG_CATEGORYMETADATA_TABLE_NAME = "blog_CategoryMetadata";
    public static final String CATEGORY_METADATA_ID_COLUMN_NAME = "category_metadata_id";
    public static final String CATEGORY_ID_COLUMN_NAME = "category_id";
    public static final String METADATA_KEY_COLUMN_NAME = "
        metadata_key";
    public static final String METADATA_VALUE_COLUMN_NAME = "
        metadata_value";

    public static Connection getConnection () {
        Connection conn = null;
     try {
      DriverManager.registerDriver(
              (Driver)Class.forName("com.mysql.jdbc.Driver").
                  newInstance() );

            // Build the URL we will use to connect to the database
      String connURL = "jdbc:mysql://" + SQL_HOST_NAME + "/" +
      SQL_DATABASE_NAME + "?" +
            "&user=" + SQL_USERNAME +
            "&password=" + SQL_PASSWORD;

      // Attempt to connect to the database
            conn = DriverManager.getConnection( connURL );

        } catch (com.mysql.jdbc.exceptions.jdbc4.
            CommunicationsException e) {
                logger.log(Level.SEVERE, "MY SQL NOT STARTED!", e);
        } catch (SQLException e) {
                logger.log(Level.SEVERE, "SQL ERROR!", e);
        } catch (ClassNotFoundException e) {
                logger.log(Level.SEVERE, "JDBC Driver Not Found", e)
                    ;
        } catch (InstantiationException e) {
                logger.log(Level.SEVERE, "JDBC Driver Instantiation
                    Error ", e);
        } catch (IllegalAccessException e) {
                logger.log(Level.SEVERE, null, e);
        }

        return conn;
    }
}
```

Listing E.4: Database definition server program

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