COGNITIVE CONSTRAINTS ON USING COLLABORATIVE LEARNING PORTALS: INVESTIGATING THEIR EFFECTS IN ONCOURSE CL

Piyanaat Taksaphan

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Master's Thesis Committee

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Karl F. MacDorman, Ph.D., Chair

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Anthony Faiola, Ph.D.

____

Joseph Defazio, Ph.D. (ABD)

Dedicated to my dad.

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ABSTRACT

Piyanaat Taksaphan

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Collaborative learning portals help teachers and students attain educational objectives (Ursula et al., 1997). They also reduce repeated requests for the same information (Forbes-Pitt, 2002). An effective collaborative learning portal should promote a collaborative learning environment. It is essential to ensure the usability of learning portals.

Most researchers of interface usability conduct laboratory experiments. Sellen and Norman (1992) pointed out that a laboratory environment is the least likely place to see spontaneous errors. This study investigated students using a collaborative learning portal under cognitive load. User performance with cognitive load was found to be more highly correlated with user subjective ratings of disorientation than was user performance without cognitive load. Three error patterns were observed, particularly in the cognitive-load condition. These findings indicate the importance of using cognitive load to simulate a user's level of distraction when conducting a usability evaluation. Finally, this study proposed revising the Novice-Expert Ratio Method (NEM).

CHAPTER ONE: INTRODUCTION & BACKGROUND

Introduction to Collaborative Learning Portals

Recent educational research has emphasized the benefits of collaborative learning (CL). Previous research on the positive effects of collaborative learning on student achievement has led to the development of Computer-Supported Collaborative Learning (CSCL) (Margaret, 1997). Collaborative learning portals are among the most effective CSCL tools by allowing students and instructors to share information (Margaret, 1997). Collaborative learning portals help teachers and students attain their educational objectives, since the responsibility for learning, teamwork, and time management are explicitly placed with the students while teachers can provide better coverage of the material (Ursula et al., 1997). Economic considerations also stimulate the use of collaborative learning portals by diminishing the need for campus group meeting rooms. It is possible for students to work when and where they like (Ursula et al., 1997). Moreover, collaborative learning portals eliminate duplication of efforts in the technology infrastructure and reduce repeated requests for the same information (Forbes-Pitt, 2002).

Importance of Collaborative Learning Portals

The interface usability of the learning portal is a factor in the success of a collaborative learning environment. If the interface is frustrating and cumbersome to use, students and instructors will simply refuse to use it. Instructors spend significant time and energy preparing class materials, answering questions, providing feedback, and marking assignments. Similarly, students must plan their schedules and work to turn in their reports on time. Students must be able to exchange ideas easily and quickly. This shows the importance of having a user-friendly collaborative tool. Because the purpose of a collaborative learning portal is to help promote a collaborative learning environment, it is essential to ensure that the portal itself helps reduce, or at least does not add to, the time and energy demands on students and instructors.

This study investigates the ways in which measuring user performance under cognitive load is a more accurate way of evaluating the performance of novice OnCourse CL users, and how cognitive load influences the error patterns of novice OnCourse CL users. This study also provides designers of learning portal with design recommendations.

CHAPTER TWO: LITERATURE REVIEW

Online Collaborative Learning and the Sakai Project

A portal is a categorized and personalized gateway that provides information, resources, and services. Each portal page consists of window-like areas called “portlets” or “modules” containing related information. The purpose of a portal is to collect information from disparate sources and create a single point of access to that information (Strauss, 2003; Waloszek, 2001). By integrating services and presenting portlets on the initial screen, portals reduce the need to navigate (Nielsen, 1999).

Collaborative learning (CL) takes place when students work together in small, heterogeneous groups to achieve a common academic goal, such as the completion of an assignment or a project (Ursula et al., 1997). At Indiana University Purdue University Indianapolis (IUPUI), the OnCourse CL portal is a new online collaborative learning environment. Indiana University is one of four founders of the Sakai community. The Sakai community was established when the University of Michigan and Indiana University independently began open source efforts to replicate and enhance the functionality of their course management software (CMS). Massachusetts Institute of Technology and Stanford University soon joined. With a grant from the Mellon Foundation, they formed the Sakai Project.[1] The mission of the Sakai Project is to deliver the Sakai application framework and its associated CMS tools and components. These components also support collaborative research.

[1] http://www.sakaiproject.org

Portal Interface Usability

Portals that guide users to the information they seek create a good first impression and attract more users, unlike portals that are difficult to use (Nielsen & Wagner, 1996). A poorly designed learning portal is a deterrent to students and instructors since usability problems impair productivity. Nielsen (1999) suggested a design standard for all pages on the portal. A consistent look and feel lightens the learning burden and is easier for users to know where they are and where they can go when navigating a large information space.

Cognitive Limitation in Cyberspace

"Cognitive load" or "mental workload" describes the resource bottleneck of human information processing. According to Proctor and Zandt (1993), cognitive load is the amount of mental work or effort necessary to perform a task. A high cognitive load occurs when the difference between the total cognitive load and the processing capacity of the working memory approaches zero. According to Byrne and Bovair (1997), several studies have implicated overloaded working memory in the occurrence of errors. Their experiments confirmed that post-completion errors can be produced in a laboratory as well as a naturalistic setting. One such type of error is leaving one's card in the automatic teller machine after withdrawing cash. The occurrence of this type of error depends on the level of working memory load at the time the step is to be performed. The error is made when the cognitive load is high, but not when the load is low (Byrne & Bovair, 1997).

Cognitive load theory has also been applied in the design of web-based instruction. The goal of instructional design is to optimize cognitive load for a particular learner. Differences in effectiveness between instructional formats are affected by differences in memory load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). A graphical user interface and multimedia format can increase extraneous cognitive load and limit learning. Organizing information, using consistent page layout, and adding dual-modality elements (audio and visual) all reduce extraneous cognitive load (Feinberg & Murphy, 2000).

As cited by Lindmark (2000), high cognitive load is one main conclusion related to error rate. The higher the cognitive workload, the higher the frequency of errors (Olson & Olson, 1990). Lindmark (2000) presented an analysis of symptoms and symptomatic behaviors involved in human-computer manual input. Description Error, Motor Error, and Context Error were some symptoms of high cognitive load. Examples of symptomatic behaviors included Click and Reclick, Over Scrolling, Fast Movement, and High Force. In a speech input interface, task performance was found to change based on users' cognitive load. Disfluencies, intersentential pausing, fragmented sentences, and slower speech rate were found to increase with users' cognitive load (Müller, Großmann-Hutter, Jameson, Rummer, & Wittig, 2001).

Limitations in working memory play an important role in the ability of users to learn and remember the structure of a Web site. Much research has studied the tradeoff between breadth and depth in designing a hierarchical structure for Web sites. The main tradeoff is between scanning and page traversal time. Larson and Czerwinski (1998) conducted an experiment with three categorization structures with 512 bottom level nodes each. The three structures were 8x8x8, 16x32, and 32x16. Each participant was asked to perform eight searches in each structure for a total of 24 searches. Data collected were measures of being lost, reaction times, and subjective ratings. Before the experiment, participants were tested with the visual scanning and memory span pre-tests. The result showed that subjects performed best with the 16x32 hierarchy and worst with the 8x8x8 hierarchy. It was also found that the memory span scores were slightly more correlated with subjects' reaction time than were the visual scanning scores.

An experiment performed by Chen and Wang (1997) confirms that different task types, goal-directed search and non-directed browsing, will lead to different user strategies. Users need to shorten time and effort in decision-making when conducting a goal-direct search. They do not want to be distracted by extraneous information that increases the demands on their limited capacity for cognitive processing. Eng et al. (2006) proposed a possible space of strategic behaviors similar to Chen and Wang's findings (see Figure 1).

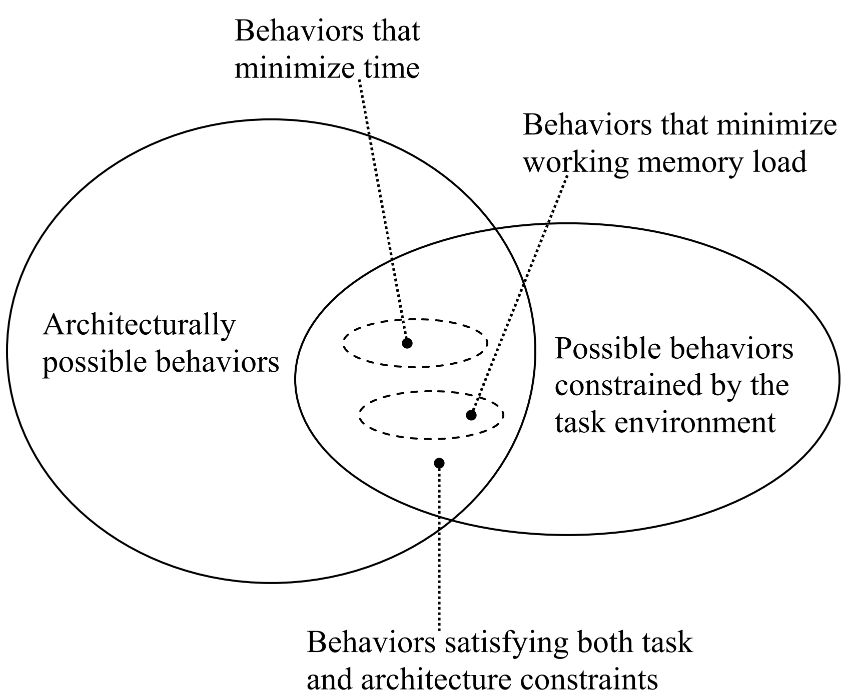

Figure 1: Figure courtesy of Eng et al. (2006): a possible space of strategic behaviors

Disorientation is another serious problem when working in electronic environments. Some research has described as feeling “lost” or “disoriented” in cyberspace (Dias, Gomes, & Correia, 1999; Eveland & Dunwoody, 2001; Sheard & Ceddia, 2004). Both poor site design and lack of experience with the medium or content may cause these feelings. In any case, disorientation will increase the cognitive load required to navigate the site (Eveland & Dunwoody, 2001).

The concept of a mental model supports this conclusion. A mental model is a dynamic but simplified and incomplete representation of a website in a user’s mind (Sheard & Ceddia, 2004). A mental model helps people simplify the task of remembering what they have seen. When a mental model is a fairly accurate representation of the actual site organization, a user can navigate the site without much mental workload. However, when the mental model does not match the actual site, navigation can be slow, and people can misunderstand what is and is not included on the site because they cannot locate its content.

Zayour and Lethbridge (2000) applied cognitive analysis to identify cognitively difficult aspects of software maintenance work. The software maintenance work begins with understanding the maintenance request. Then, the code relevant to the problem has to be located. Once the starting point of the relevant code has been located, the execution path is followed to identify the rest of the code responsible for the maintenance problem. The execution tracing is then mapped with the problem behavior. From their case study, it was found that one activity particularly exhausts the capacity of working memory. This was the disorientation that the software engineer suffers during code exploration. The authors explained that the disorientation occurs where the software engineer fails to maintain a cognitive map that describes the relation among the related artifacts he has visited during his current exploration due to the limitation of the short-term memory. They concluded that the short-term memory overload is the main source of cognitive difficulties, including disorientation.

It should be possible to predict a user's performance and error patterns by comparing the user's mental model with the system model of a website. Kellogg and Breen (1987) claimed that user errors can be understood once a model of user knowledge has been derived. With experience, a user's mental model will come to approximate the system model. Errors and difficulties in performance will result, suggesting the need to improve system usability.

The work of Nakayama, Kato, and Yamane (2000) has proven the effectiveness of this concept. They proposed a technique that revealed the gap between Web site designers' expectations and users' behavior. The former were assessed by measuring the inter-page conceptual relevance and the latter by measuring the inter-page access co-occurrence. Under their assumption, Web designers expect conceptually related pages to co-occur in the same visit if the site is well designed. Thus, by plotting both data on the same graph, the gap between designers and users is revealed.

Another example is the work of Urokohara, Tanaka, Furuta, Honda, and Kurosu (2000), who proposed a Novice-Expert ratio Method (NEM) for measuring user performance based on the concept of the mental model. This method compares the time required by a novice and expert users. The rationale for this method is that usability problems may arise from the discrepancy between the designer's system model and the user's mental model. Urokohara et al. (2000) assumed that the amount of mismatch between the system model and the user's model will result in a difference in the time required to complete a task. Urokohara et al. (2000) explained that the actual value of time is not as important in considering the time difference as is the ratio of the two time measures between the novice user and the expert user. The time for completing the whole procedure does not tell the analyst which parts of the interface cause usability problems and how difficult it is for novices to perform particular steps. In contrast, the NEM method compares novices' and experts' time step by step, so that the steps that required a long time to achieve can be identified. This ratio also represents the degree of difficulty of that specific procedural step. Their findings have confirmed the usefulness of this method.

Knowledge Gap

Most studies of interface usability experiments are conducted under laboratory conditions. This is not enough to elicit usability errors and difficulties that users encounter in a real environment. Sellen and Norman (1992) pointed out that a laboratory environment is the least likely place to find spontaneous, absent-minded errors. A laboratory-setting experiment usually has participants work on only one task at a time. In real environments, students are in a cognitively constrained situation in which multiple tasks, interruptions, and distractions are competing for attention and working memory. In using a learning portal, students might be rushing to print out reading materials for class or submitting their homework while planning their schedules.

Research Questions and Hypotheses

This study investigates how cognitive limitations affect the user. More specifically, based on the observations of novices using the OnCourse CL portal, this study investigates the effects of cognitive load on user performance and error patterns.

RQ1: Do measurements of the performance of novice users of OnCourse CL, under cognitive load, provide a better metric than those under controlled observation and, if so, in what way are the measurements better?

H1: Subjective measures of disorientation correlate better with user performance scores under cognitive load than under controlled observation.

RQ2: How does cognitive load influence the error patterns of novice users of OnCourse CL?

RQ3: From the error patterns found in the experiment, what design recommendations would help learning portal designers' to create usable learning portals?

CHAPTER THREE: METHODOLOGY

Cognitive Modeling Technique

The findings of the interviews and observations in Phase 1 of this study elicit the problem of navigation through the portals. The participants often reported that the system did not perform as expected. This interested the researcher to compare the novice users' time-on-task to that of the expert users. Therefore, this research employed a user performance measurement method, the Novice-Expert ratio Method (NEM) proposed by Urokohara, Tanaka, Furuta, Honda, and Kurosu (2000).

$$NE\ Ratio = \frac{Novice\,(TN)}{Expert\,(TE)}$$

$$User\ Performance = \frac{Number\ of\ task\ steps\,(S) - NE_{high}}{Number\ of\ task\ step\,(S)}$$

However, the original method proposed by Urokohara et al. (2000) does not account for the data from participants who did not finish the task. Inability to complete a task is considered a severe usability problem, so this research proposed a revised method of calculating NE ratio and user performance.

A Revision of the Novice-Expert ratio Method

This research replaced the data of the first unfinished step by the maximum time allowed for one step, which is 18 * expert-time-on-step. If any steps took longer time than the maximum time, the data would also be replaced by the maximum time. The steps following the first unfinished step were excluded from the calculation. All incomplete steps were considered as steps with a high NE ratio. As a result, the equation was revised to exclude incomplete steps in addition to steps with a high NE ratio.

$$User\ Performance = \frac{Number\ of\ task\ steps\ (S) - NE_{high} - Number\ of\ incomplete\ steps}{Number\ of\ task\ step\ (S)}$$

Table 1: The revised method of calculating NE ratio proposed by this research

Steps	Replaced by
The first unfinished step	The maximum time allowed for one step, which is 18 * expert-time-on-step
The steps following the first unfinished step	Excluded from the calculation
The steps took longer time than the maximum time	The maximum time allowed for one step, which is 18 * expert-time-on-step

KLM-GOMS

Expert performance has been simulated in human-computer interaction using Goals, Operators, Methods, and Selection rules (GOMS) (Card, Moran, & Newell, 1983, as cited in John & Kieras, 1996). The goals are what the user has to accomplish. An operator is an action performed in service of a goal. Methods are sequences of operators and sub-goal invocations that accomplish a goal. If more than one method is applicable to a goal, then selection rules are required to represent the user's knowledge of which method should be applied. According to John and Kieras (1996), the KLM-GOMS is the simplest GOMS technique. Methods in KLM-GOMS are limited to being in sequence and containing only primitive keystroke-level operators. These operators are

- K to press a key or button
- P to point with a mouse to a target on a display
- H to home hands on the keyboard or other device
- D to draw a line segment on a grid
- M to mentally prepare to perform an action or a closely related series of primitive actions
- R to represent the system response time during which the user has to wait for the system

KLM-GOMS was used to estimate expert performance instead of data from actual experts because of the difficulty of finding a sufficient number of participants with expertise in OnCourse CL and it is also hard to control the level of expertise.

Software Tools

Participants were asked to perform tasks on OnCourse CL[2] learning portal using Internet Explorer version 6.0 on Windows XP operating system. The screen resolution was set at 1024x768 on the 15” monitor. User activities and mouse movements were recorded using the LogSqare[3] tool. The cognitive performance modeling tool “CogTool[4]” was employed to create a Keystroke-Level Model (KLM-GOMS) of each task to estimate the amount of time that expert users would require to complete it.

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2 https://oncourse.iu.edu/portal
3 http://www.mangold.de/english/logsqare.html
4 http://www.cs.cmu.edu/~bej/cogtool

Samples and Participants

Forty-one people participated in this study: five participants in Phase 1 and 36 in Phase 2. Since the user base of the OnCourse CL portal is IUPUI students, this study drew from this population.

For Phase 1, purposive sampling was used to ensure that participants had sufficient portal experience. The interviewees were three undergraduate students, one graduate student, and one IUPUI faculty member. For Phase 2, the within-subject method was used. Participants were recruited using convenience sampling, which means the selection was based on their availability and convenience. Minors were excluded from the study to simplify the design.[5] The participants did not receive payment for taking part in the study.

The minimum requirement for all participants was regular computer use and moderate Internet experience. This was defined as follows:

1. A regular computer user:
    a. Is familiar with the PC or Macintosh, including mouse, keyboard, and graphical user interface (GUI), and has at least one year of experience
    b. Knows how to use a Web browser. Has at least one year of experience
    c. Has good eyesight, at least with correction.
2. A moderate Internet user:
    a. Uses the Internet at least three days per week.

[5] This is justified because most learning portals are designed to be used by college students and because the study focuses on human performance, not subject variables or individual differences. No individual was excluded from participation on the basis of gender, race, color, national origin, religion, creed, disability, veteran's status, sexual orientation, or age.

Procedures

There are two phases in the study. The interviews and observations in the first phase of the study were intended to collect data on the experience of using a collaborative learning portal OnCourse CL. The second phase consisted of usability testing of the file system interface on OnCourse CL. The findings are used to test the hypotheses.

Phase 1: Interview

The interviewees were three undergraduate students, one graduate student, and one IUPUI faculty member. First, the participants were asked to fill out the pre-test questionnaire in which they provided demographic data and described their familiarity with computers, the Internet, and OnCourse CL. After that, participants were interviewed about their use of OnCourse CL. The interview findings indicated that students and faculty members commonly use the file manager, announcements, and the assignment tool. To narrow the scope of this research, the researcher focused on the file manager because misuse of the file manager can have catastrophic consequences such as loss of data. OnCourse CL has two file manager tools. The first one, "Resources," allowed users to make materials available online. At IUPUI, the Resources tool was also the central file storage service for students, faculty, and staff. The other file manager tool was the "Drop Box." The Drop Box allowed instructors and students to create private folders for document sharing. The Drop Box, like Resources, allowed users to upload many types of files at a time. The Drop Box allowed nested folders. Instructors could use the Drop Box tool to share private progress reports with students.
(https://oncourse.iu.edu/portal/help/main)

Phase 2: Experiment

There were 36 participants in this phase. Each participant performed usability testing with a think-aloud protocol. Participants were asked to perform five tasks on the OnCourse CL portal. The goal of the first two tasks was to familiarize participants with the OnCourse CL interface. They were relatively simple, warm-up tasks to make the participants comfortable with the system. The remaining tasks were used to test the hypotheses, and to capture usability problems with the Resources and Drop Box tool. (See Appendix D.)

Each participant performed the same sequence of tasks twice; once with the cognitive-load constraint, and once without. To cross balance for the effect of learning, half of the participants started with the high cognitive load condition first and the other half started without a cognitive load. In addition, the order of the tasks was varied (see Appendix E).

In the high cognitive-load condition, a 3x3 table randomly filled with seven letters similar to

Figure **2** was presented to the participants before the start of each task. The participants had 30 seconds to memorize the table. They were told that after finishing the task they would have to fill out a blank 3x3 table exactly like the one they were being presented. While performing the task, rehearsal was allowed as necessary.

Mouse click events and time were recorded in detail for each task. Any problems that participants encountered while performing the tasks were documented.

The experiment concluded with a post-test questionnaire and a follow-up interview. The questionnaire was used to elicit user demographic data and experience with computers, the Internet, and OnCourse CL. A post-test interview was used to acquire additional qualitative data about user experience with OnCourse CL. Participants were allowed to browse through the interface they used to recall problems and to express opinions. Note taking and the LogSqare logging tool were used to collect data.

K		P
U	J	G
	Q	B

Figure 2: Example of a 3x3 table used as a secondary task

Statistical Analysis

The goal of the interview sessions in the first phase was to learn users' attitudes, expectation, assumptions and experiences about the OnCourse CL portal.

In the second phase, users performed usability testing tasks with the think aloud technique. To measure user performance, users were asked to perform tasks and the test was timed. The independent variable in this study is interface design and the dependent variables are user performance score and error patterns.

User Performance

A performance score in this experiment was calculated using the NEM concept proposed by Urokohara et al. (2000):

$$NE\ Ratio = \frac{Novice(TN)}{Expert(TE)}$$

The novice's time-on-task was obtained from the experiment, whereas the expert's time-on-task was calculated using KLM-GOMS because it was hard to control the level of expertise of the participants. User performance is a percentage of operational steps with a low NE ratio. This study used the revised user performance equation explained earlier:

$$User\ Performance = \frac{Number\ of\ task\ steps\ (S) - NE_{high} - Number\ of\ incomplete\ steps}{Number\ of\ task\ step\,(S)}$$

Derived from the chi-square method, an NE ratio of around 4.5 was found to be critical in differentiating low and high NE ratios (Urokohara et al., (2000). This research also used this criterion. In other words, steps that were determined to have a high NE ratio are steps with NE ratio greater than 4.5.

Error Patterns

Errors were compared to and classified according to the categorization of slips proposed by Norman (1981) as cited in Lindmark (2000). These categories are

- Errors in the formation of intention
    - Context errors
    - Description errors
- Errors resulting from a faulty activation of the action schemas
    - Unintentional activation
    - Loss of activation
- Errors that result from faulty triggering

CHAPTER FOUR: RESULTS

Phase 1: Interview

The time periods in using OnCourse CL ranged from 3 to 15 minutes for the student participants, and 60 minutes for the faculty participant. All participants access OnCourse CL once a day, mostly every weekday.

All of the students reported that they could not choose whether or not to use OnCourse because it was the instructor's decision. The students were asked how they use OnCourse CL. The students use between three and five tools. The most commonly used tool is the Announcements. Students reported that they check the Announcements before class and before downloading assignments. The use of other tools depends on the course. Some courses require students to submit weekly assignments using the Assignments tool, whereas other courses use the Drop Box. One participant found this confusing because these functions overlap and were used differently from course to course. Courses with weekly readings use the Resources tool to post the readings. After listing the tools they use, the participants were asked to use those tools as if they were in a real situation.

Using think-aloud protocol, participants reported that they were seeing an unexpected page. Two out of five participants reported that they "get lost" while using OnCourse CL: "I don't know where I am," "There is no clue." (OnCourse CL remembers the last page the user visits for each tool. When users navigate to any other tool or course and go back to the previous one, they do not remember where the last page was visited. The tool's home page was expected. However, what the participants saw was the last page visited in that tool. This might explain why the users were confused and reported seeing an unexpected page.)

Common problems occurred when the participants were trying to go up one level and/or go back to the top level after they navigated further from each tool's home page. Two participants were trying to use the browser's back button only to find it took them to the unexpected page. Both of them tried several times before giving up. Encountering the same problem, another participant said, "I forgot. The back button doesn't work here." The two participants who navigated back correctly (using the up arrow in front of the panel's name) immediately acknowledged that they had misused the browser's back button before but now remembered that they had to use this up-arrow button. However, excessive hitting of this button was observed. Participants were often unsure whether they were already at the top level and therefore would hit the button until they saw the same pages twice. (The up-arrow button remains active even when there is no upper-level page. If the user is currently at the very top page, the up-arrow button will reload this current page instead. There is a breadcrumb navigation trail telling the users where they are, but the participants, surprisingly, did not see it.)

One participant noticed that the tools listed on the left-hand side varied from one course to another. This participant and the faculty participant explained that their mental model of OnCourse CL is like a tree, while the rest described a mental model that is more similar to a matrix.

When asked about how course links on the top are sorted, only one participant knew that they are sorted alphabetically. The other four participants answered that they have no idea. Their guesses were, listed alphabetically, randomly, and by frequency of use. All participants prefer the course links to be grouped by semester as they were in the original version of OnCourse.

Phase 2: Experiment

To make sure that data collected under the cognitive-load condition was valid, recall scores were used to screen out data from the participants who might not have been trying hard enough to remember the letters while performing the tasks. Data of the participants with recall scores of less than the mean-SD were excluded from the NEM analysis process. This resulted in totally screening out the data from five participants.

Task Analysis

The first step in calculating the user performance score using NEM was defining each step of the usability testing tasks. Since the first two tasks in the experiment were used only to familiarize participants with the interface of OnCourse CL, these tasks will not be considered. The following section will define and illustrate steps in completing Task 3, Task 4, and Task 5.

Task 3

Participants were asked to go to IN INFO PRAC 001282 class's Resources tool and download the file named "LectureNoteWeek5.doc" inside the folder "Lecture Notes" to the desktop.

Steps
1. Select "IN INFO PRAC 001282" 2. Select "Resources" 3. Select "Lecture Notes" folder 4. Select file "LectureNoteWeek05.doc" 5. In "File Download" popup window , select "Save" 6. In "Save As" popup window, select "Save"

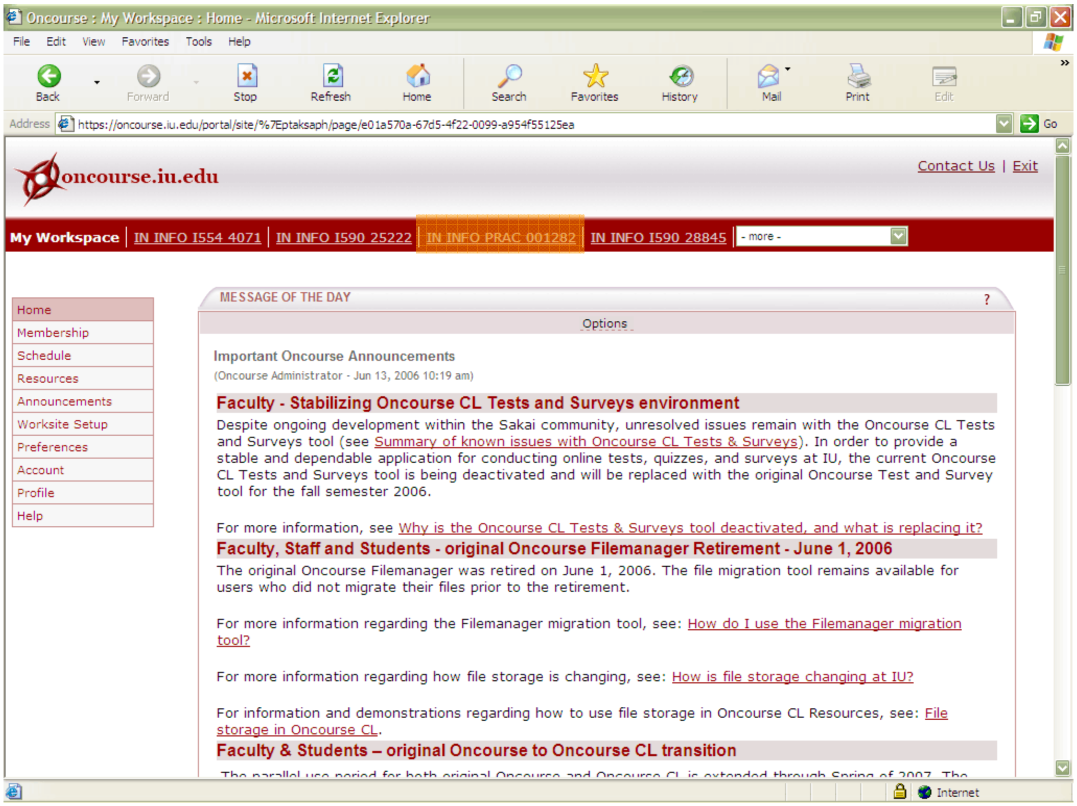


Figure 3: Snapshot of Task 3 - Step 1

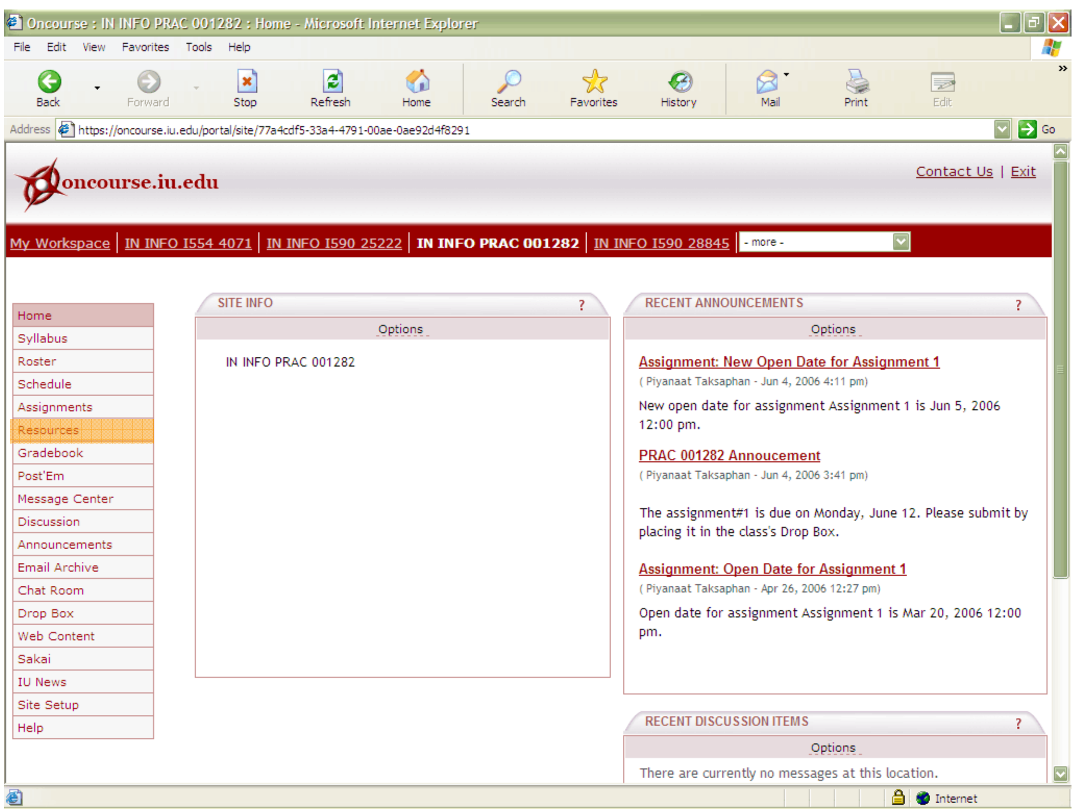


Figure 4: Snapshot of Task 3 - Step 2

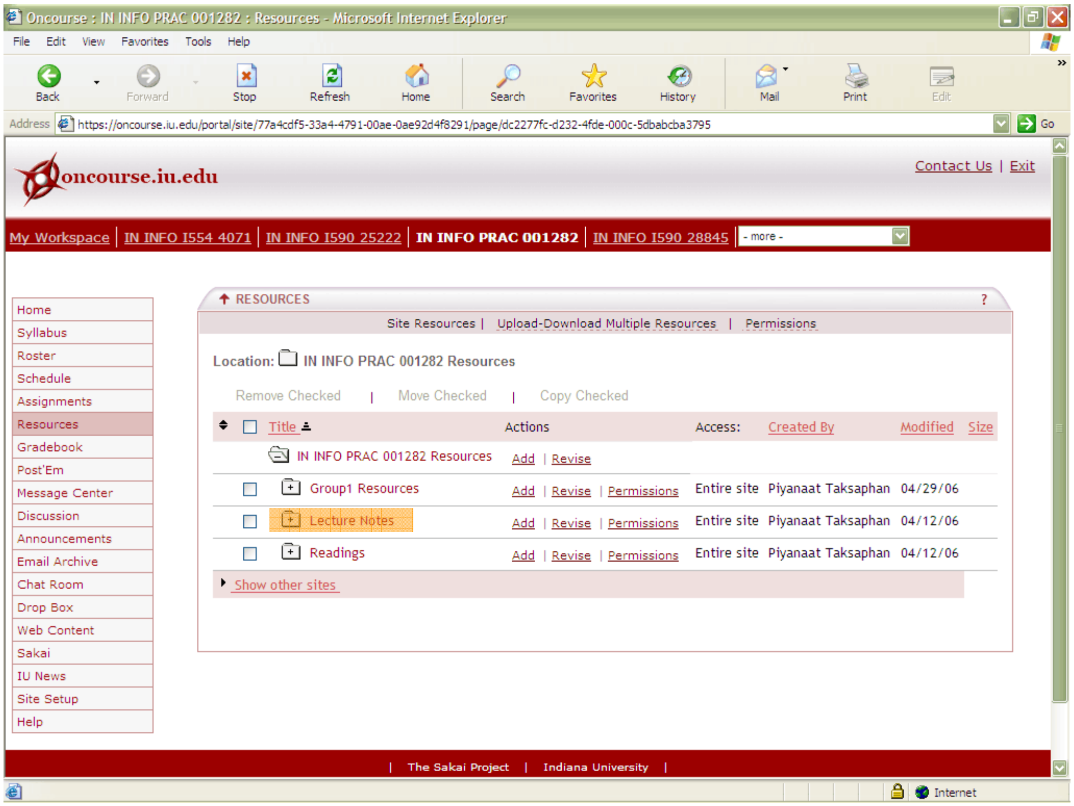


Figure 5: Snapshot of Task 3 - Step 3

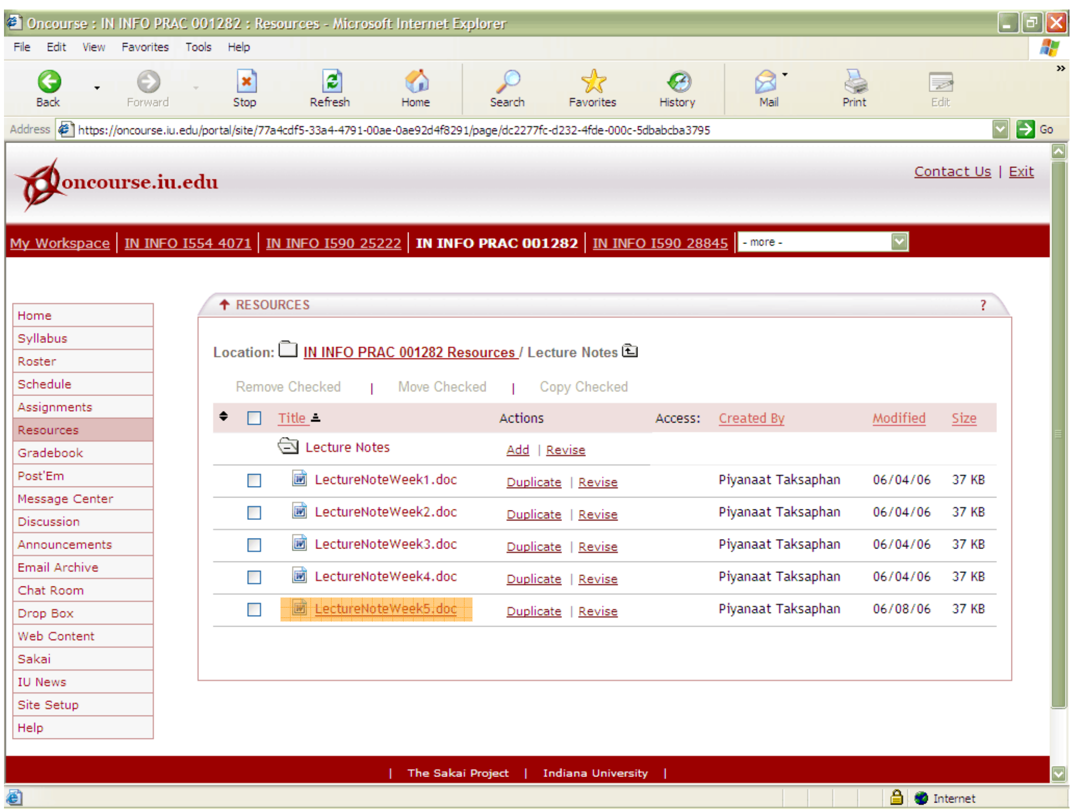


Figure 6: Snapshot of Task 3 - Step 4

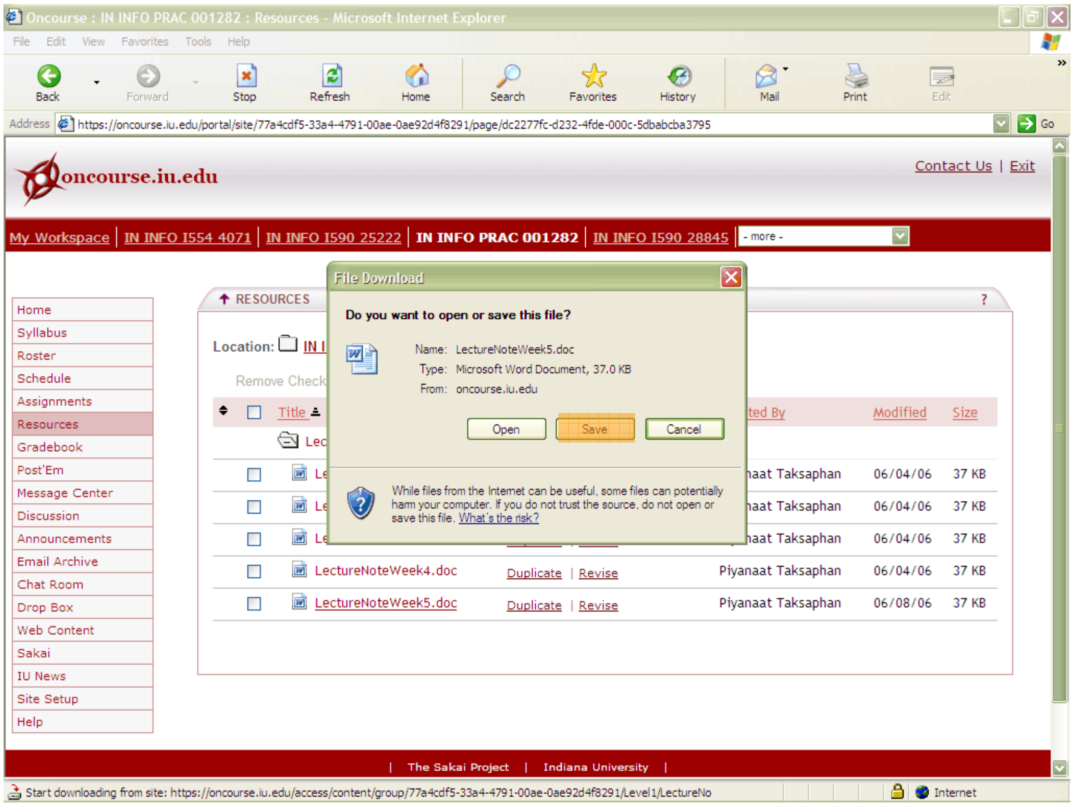


Figure 7: Snapshot of Task 3 - Step 5

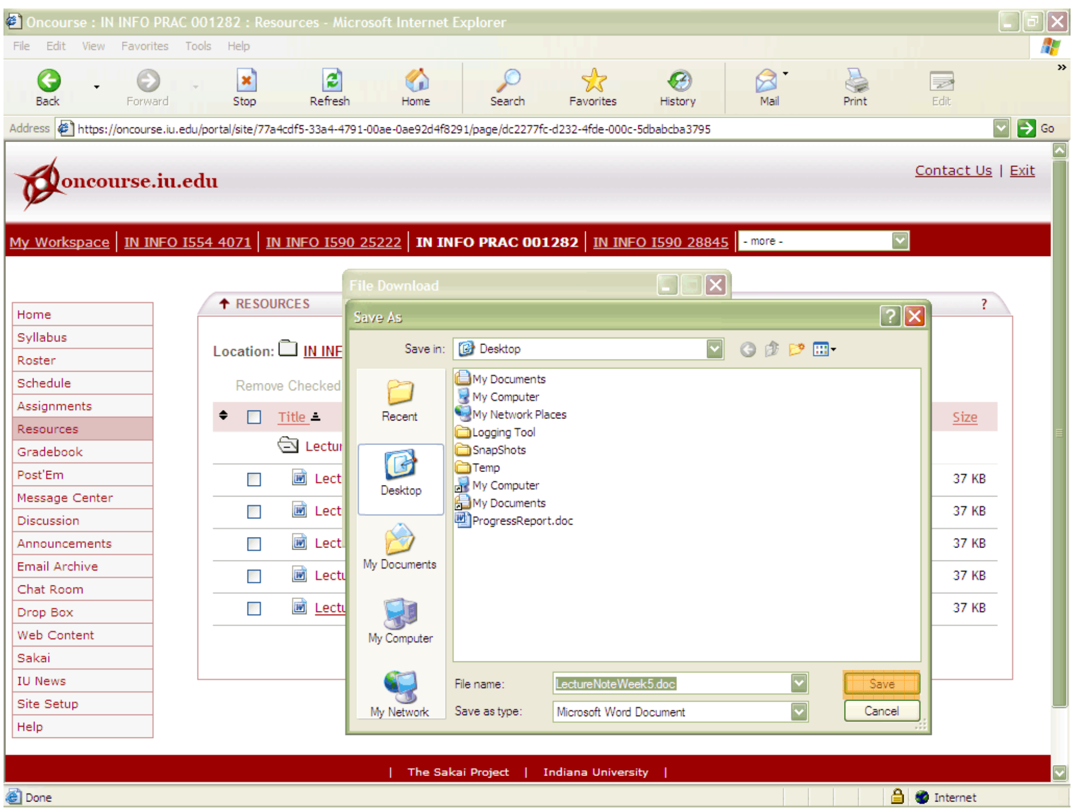


Figure 8: Snapshot of Task 3 - Step 6

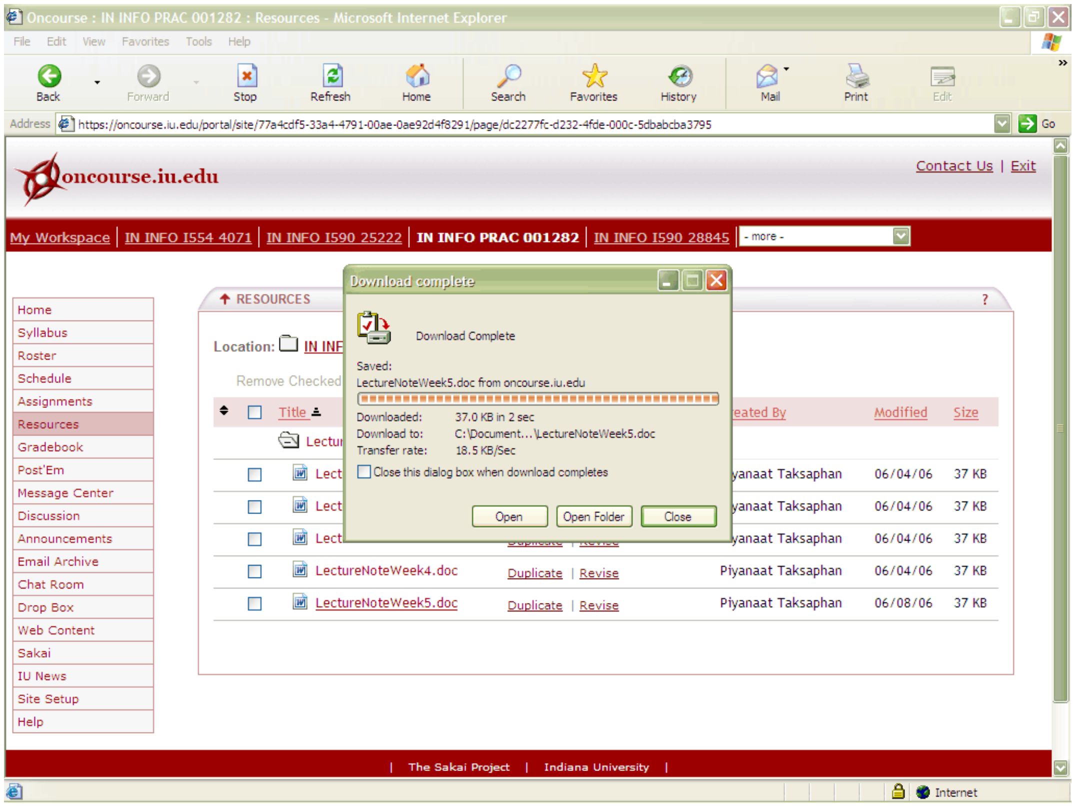


Figure 9: Snapshot of Task 3 - Task Finished

Task 4

Participants were asked to go to the IN INFO PRAC 003074 class's Drop Box and move the "MidtermReport_Comments.doc" file to the "Midterm Project" folder.

Steps
1. Select "More" drop-down
2. Select "IN INFO PRAC 003074"
3. Select "Drop Box"
4 .Select checkbox in front of "MidtermReport_Comment.doc"
5. Select "Move Checked"
6. Select "Paste Moved Items"

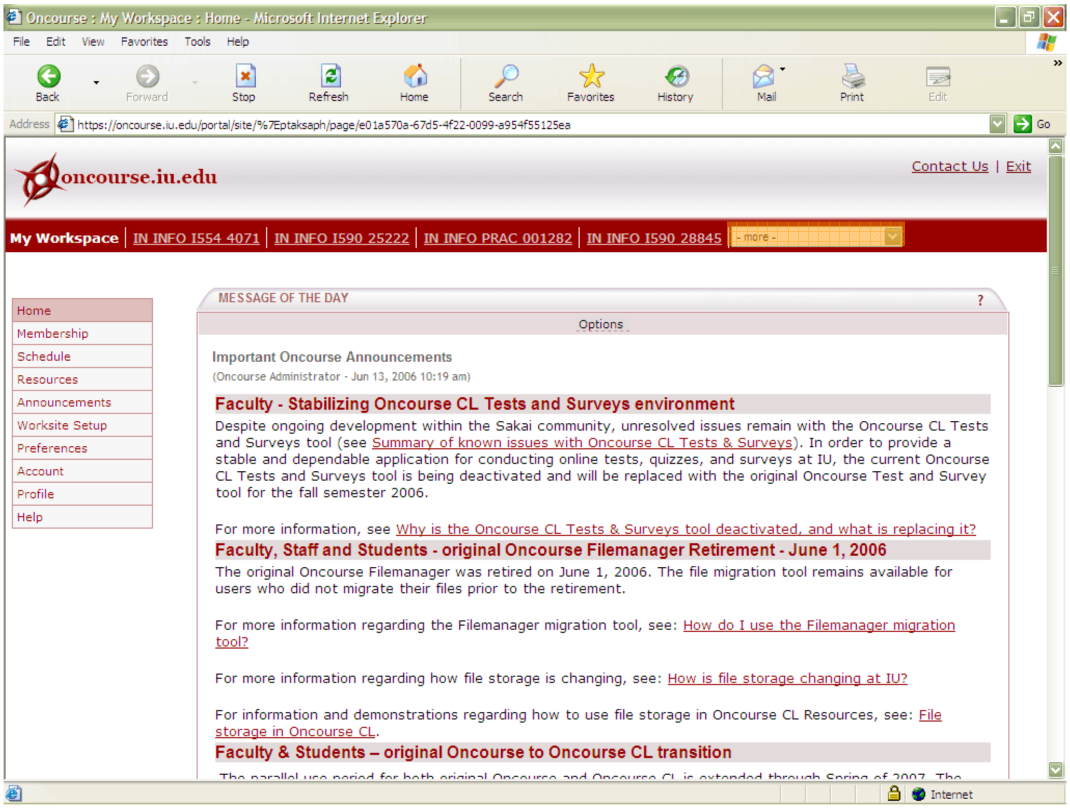


Figure 10: Snapshot of Task 4 - Step 1

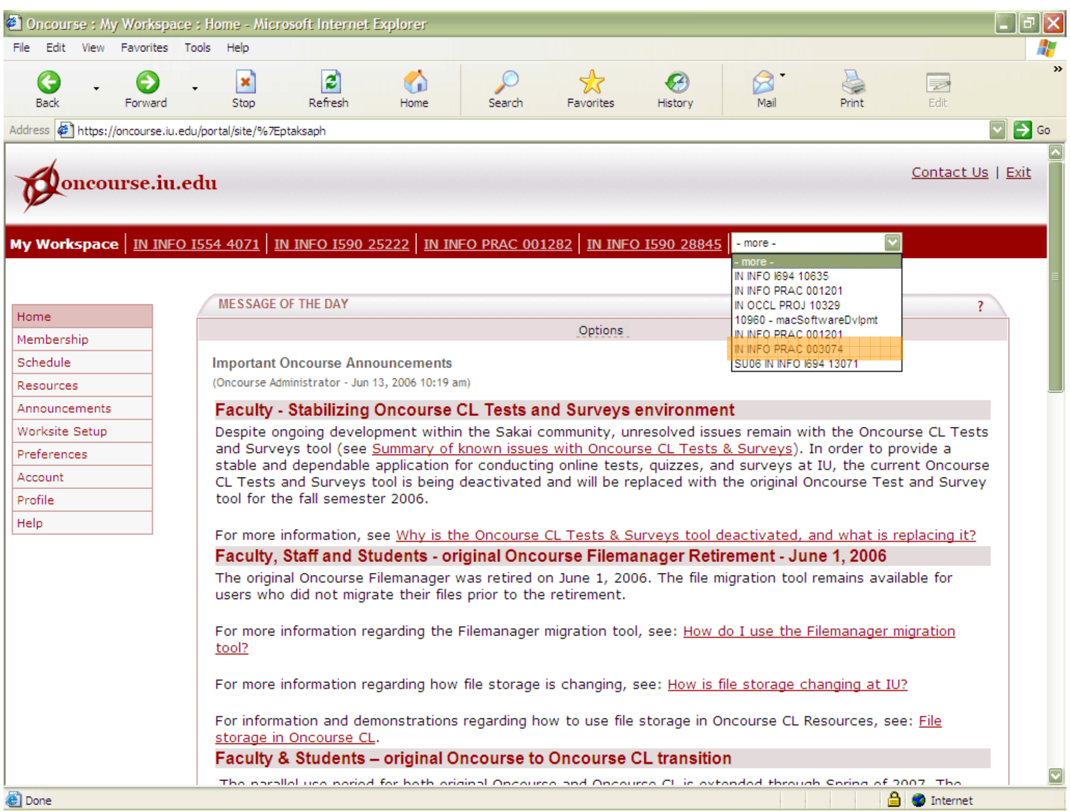


Figure 11: Snapshot of Task 4 - Step 2

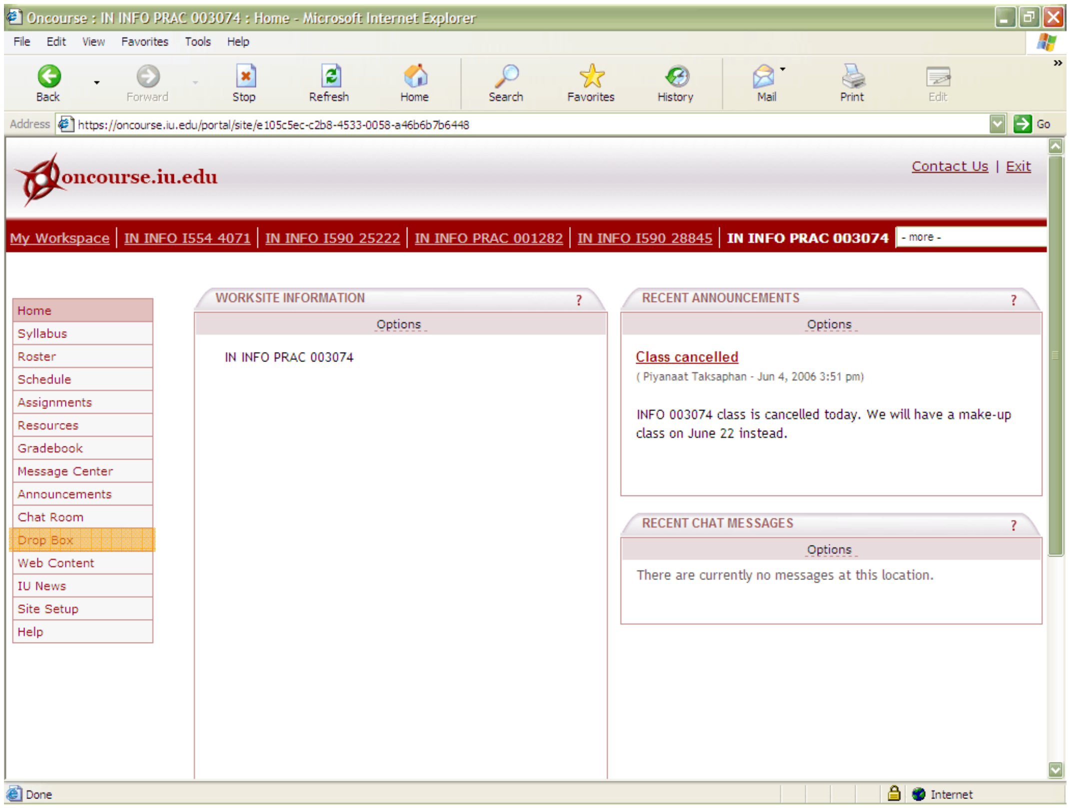


Figure 12: Snapshot of Task 4 - Step 3

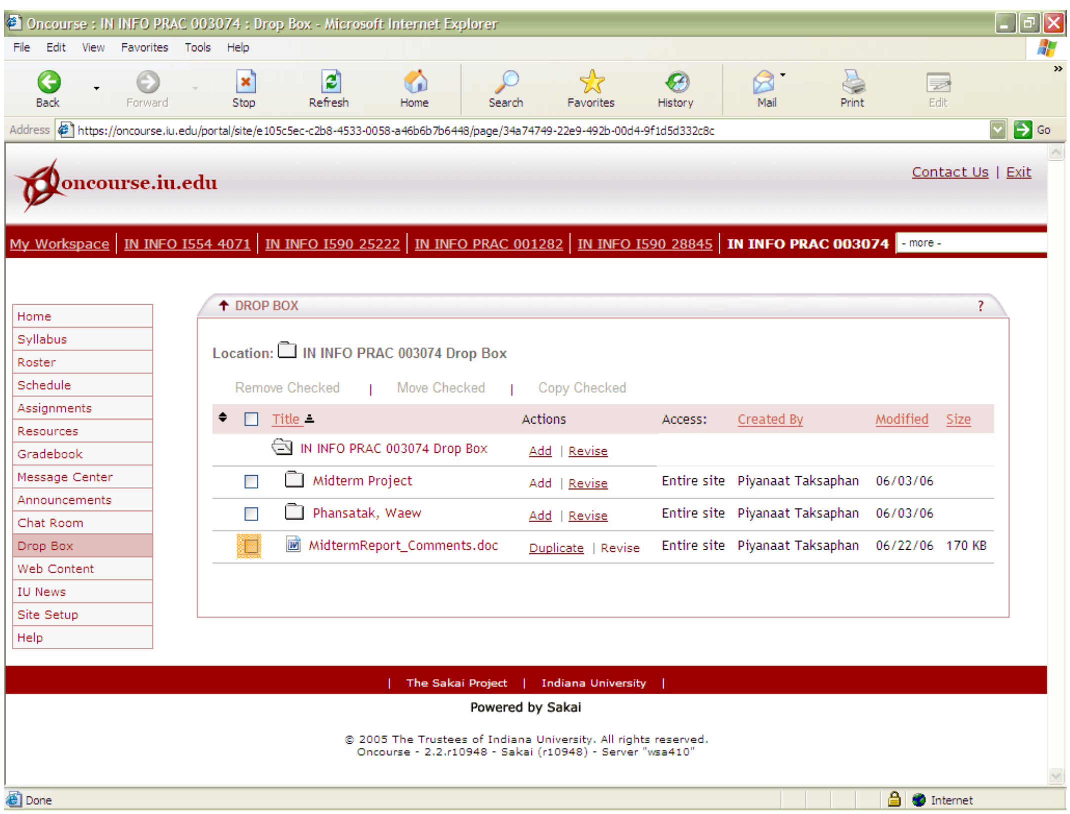


Figure 13: Snapshot of Task 4 - Step 4

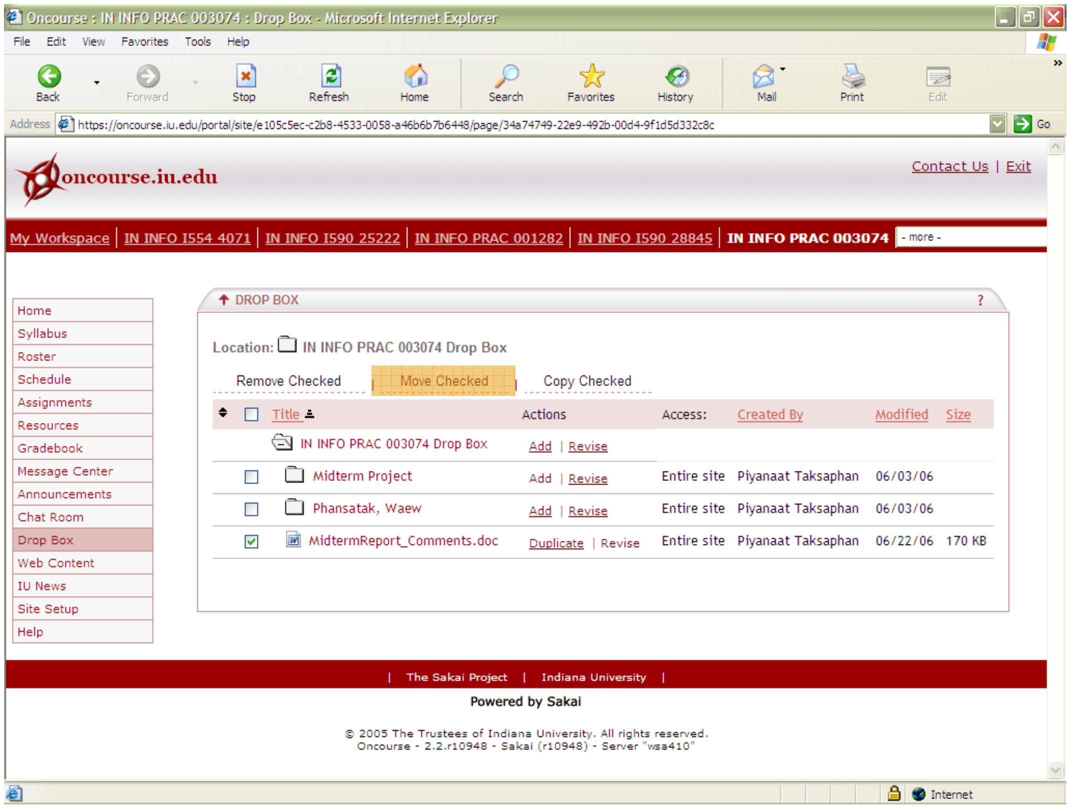


Figure 14: Snapshot of Task 4 - Step 5

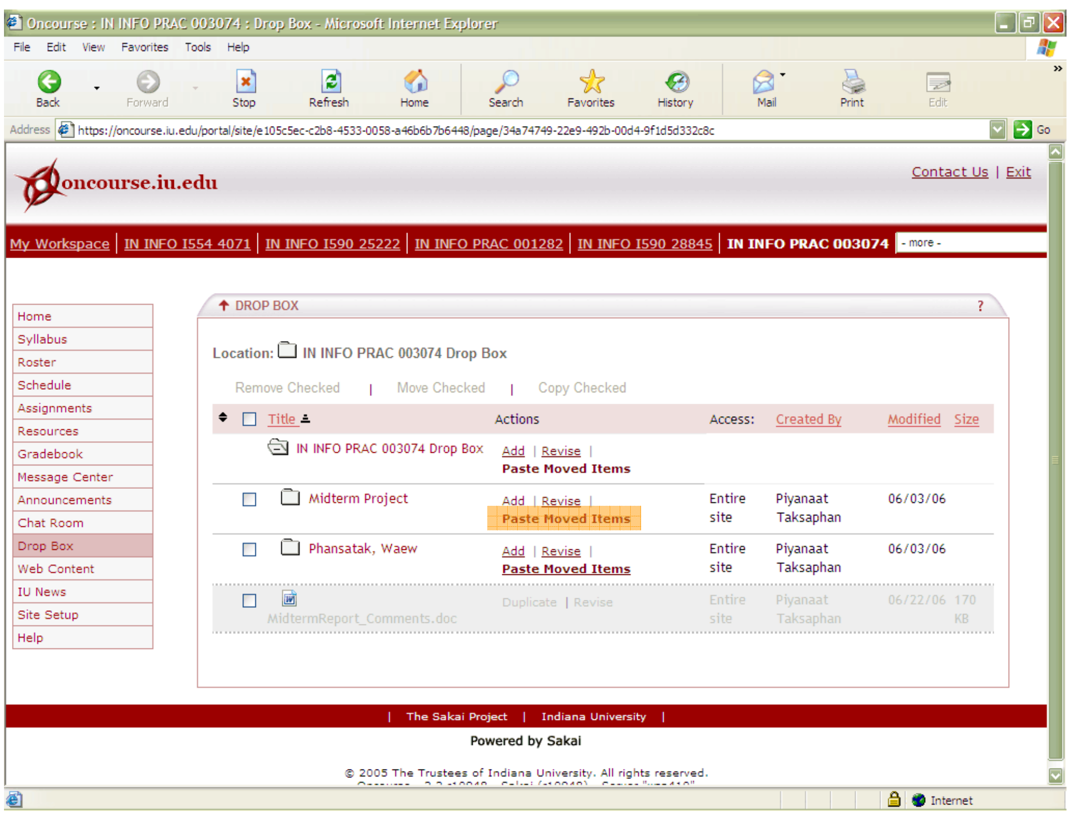


Figure 15: Snapshot of Task 4 - Step 6

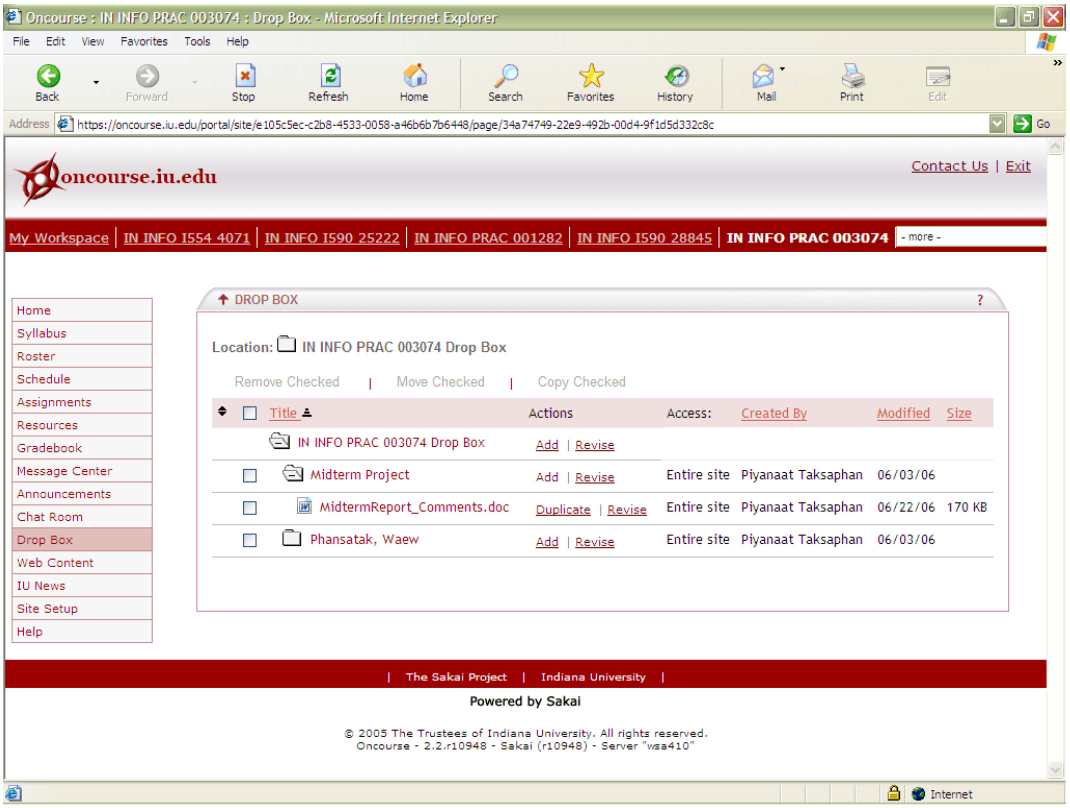


Figure 16: Snapshot of Task 4 - Task Finished

Task 5

Starting from IN INFO PRAC 001282 class's Drop Box, Participants were told to create a new folder called "Final Project" and then place a file named "ProgressReport.doc" on the desktop into this folder.

Steps
1. In IN INFO PRAC 001282 class's Drop Box, select "Add"
2. Select drop-down menu (currently showing File Upload)
3. Select "Empty Folder"
4. Enter folder name "Final Project"
5. Select "Add" button
6. Select "Add"
7. Select "Browse…"
8. Select "ProgressReport.doc"
9. Select "Open"
10. Select "Add" button

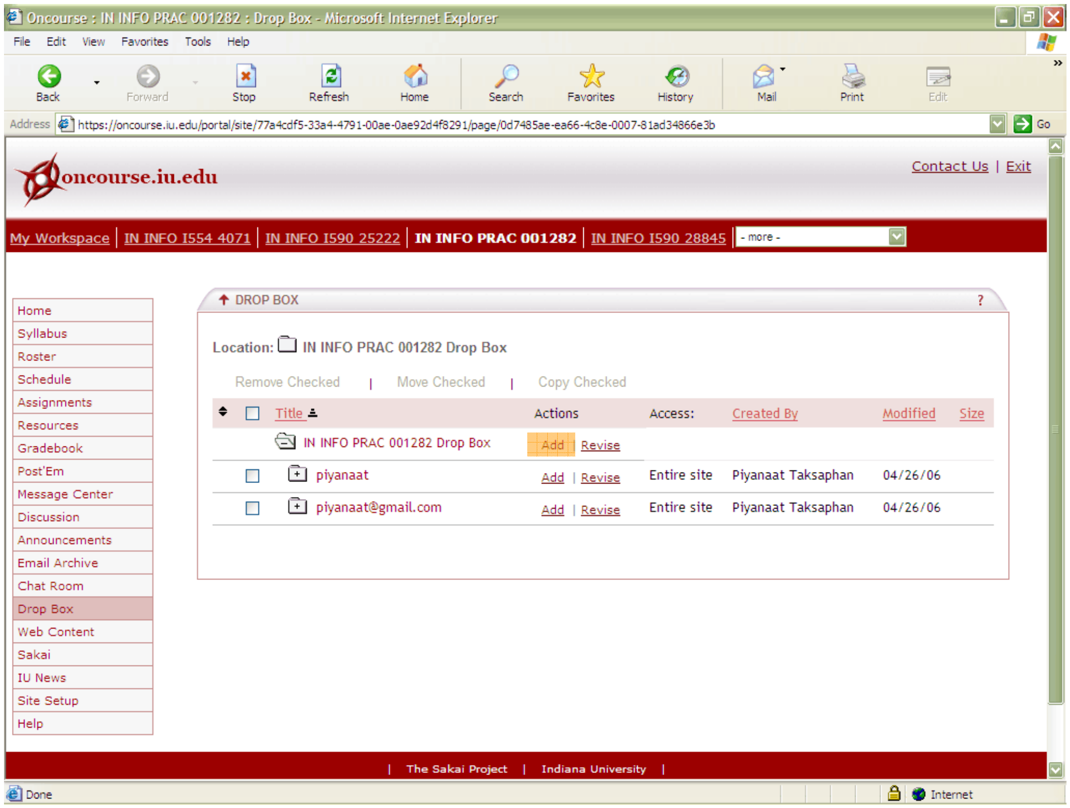


Figure 17: Snapshot of Task 5 - Step 1

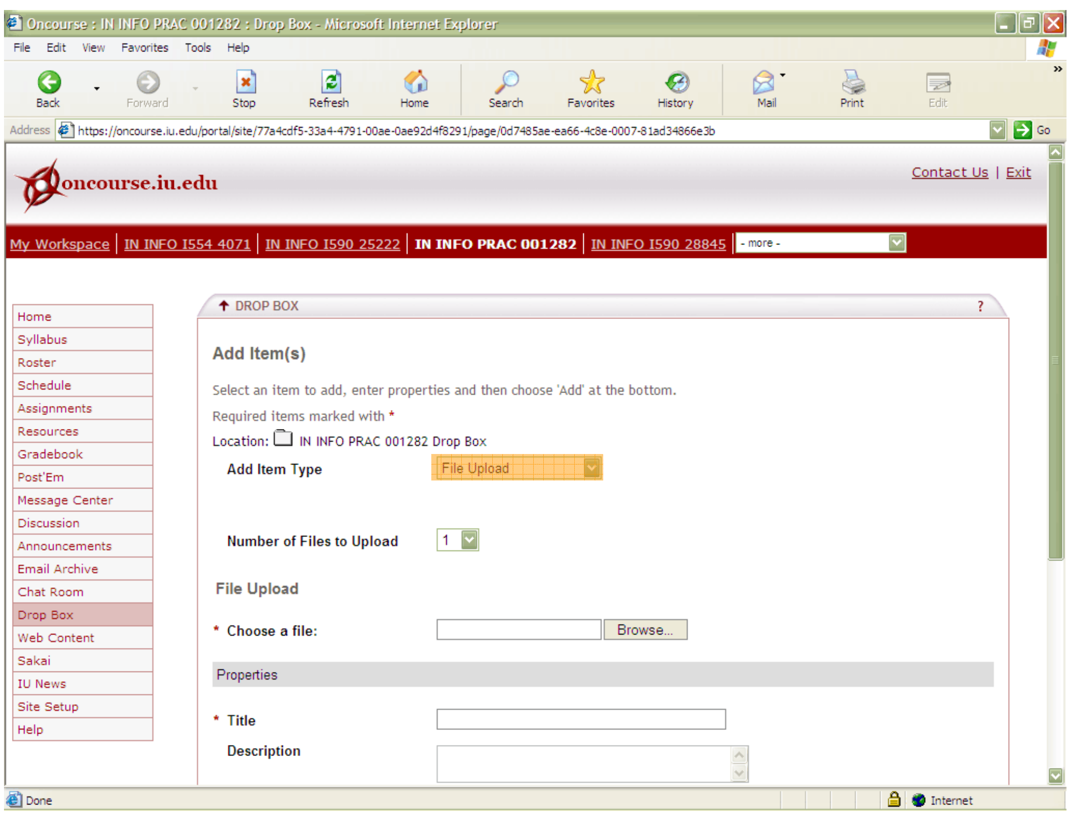


Figure 18: Snapshot of Task 5 - Step 2

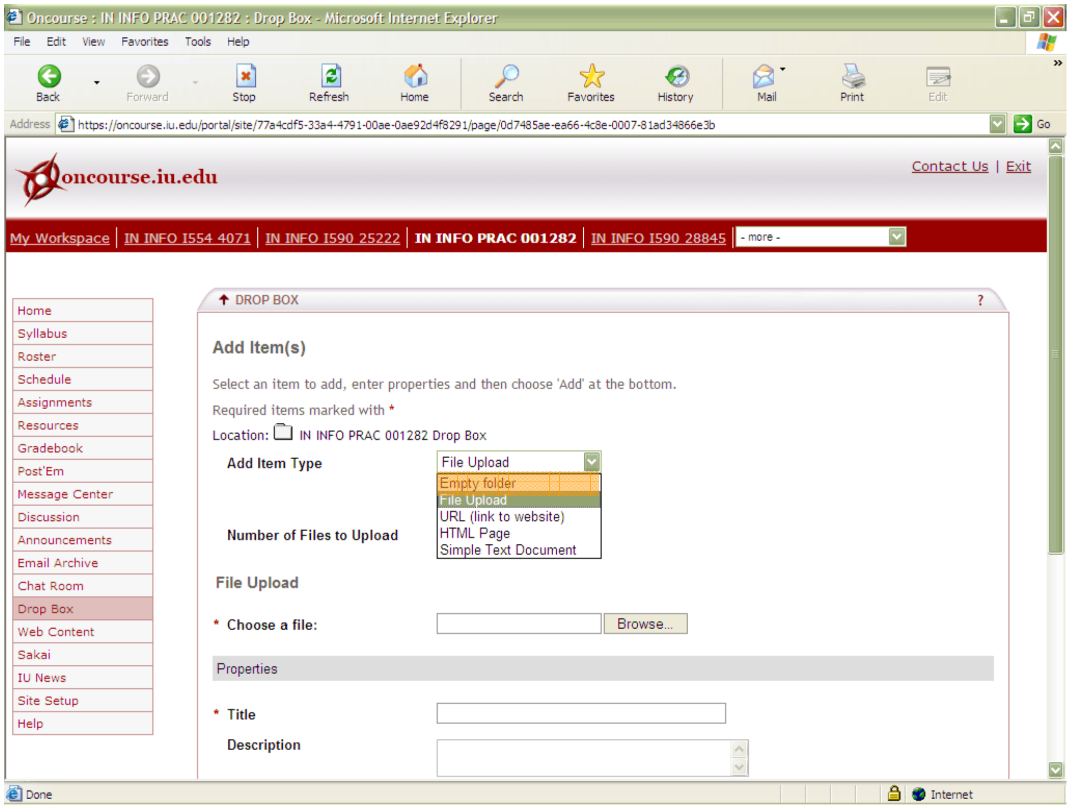


Figure 19: Snapshot of Task 5 - Step 3

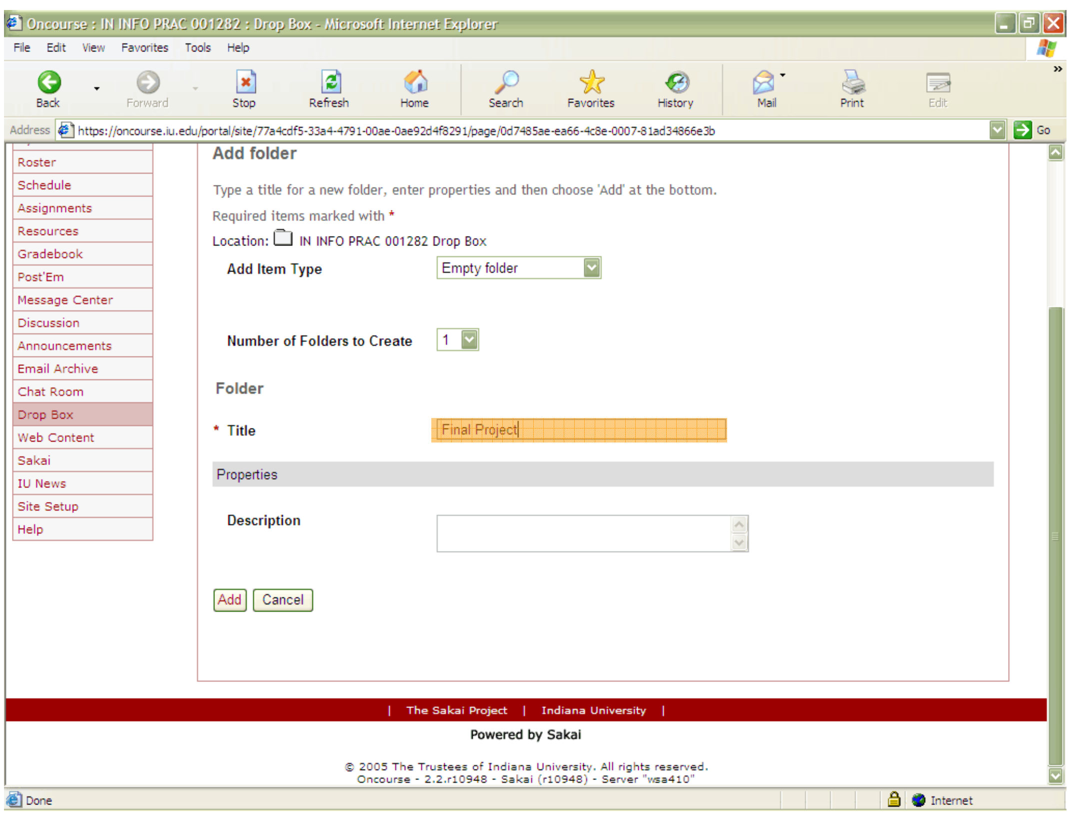


Figure 20: Snapshot of Task 5 - Step 4

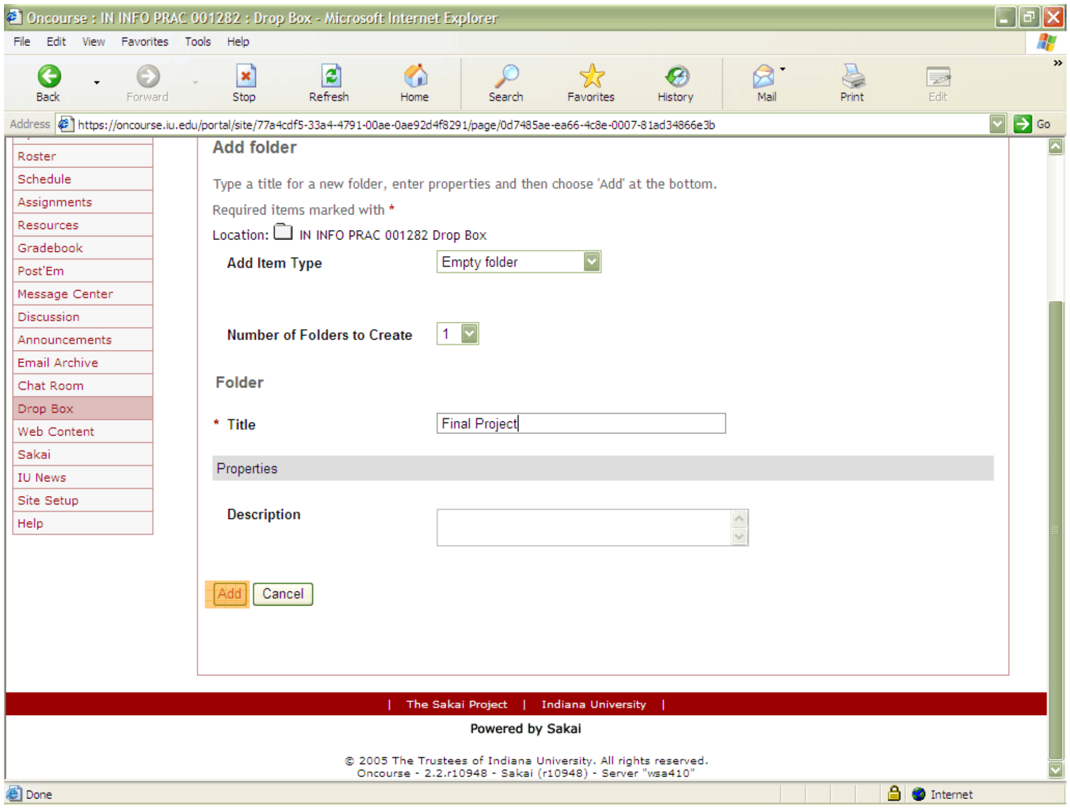


Figure 21: Snapshot of Task 5 - Step 5

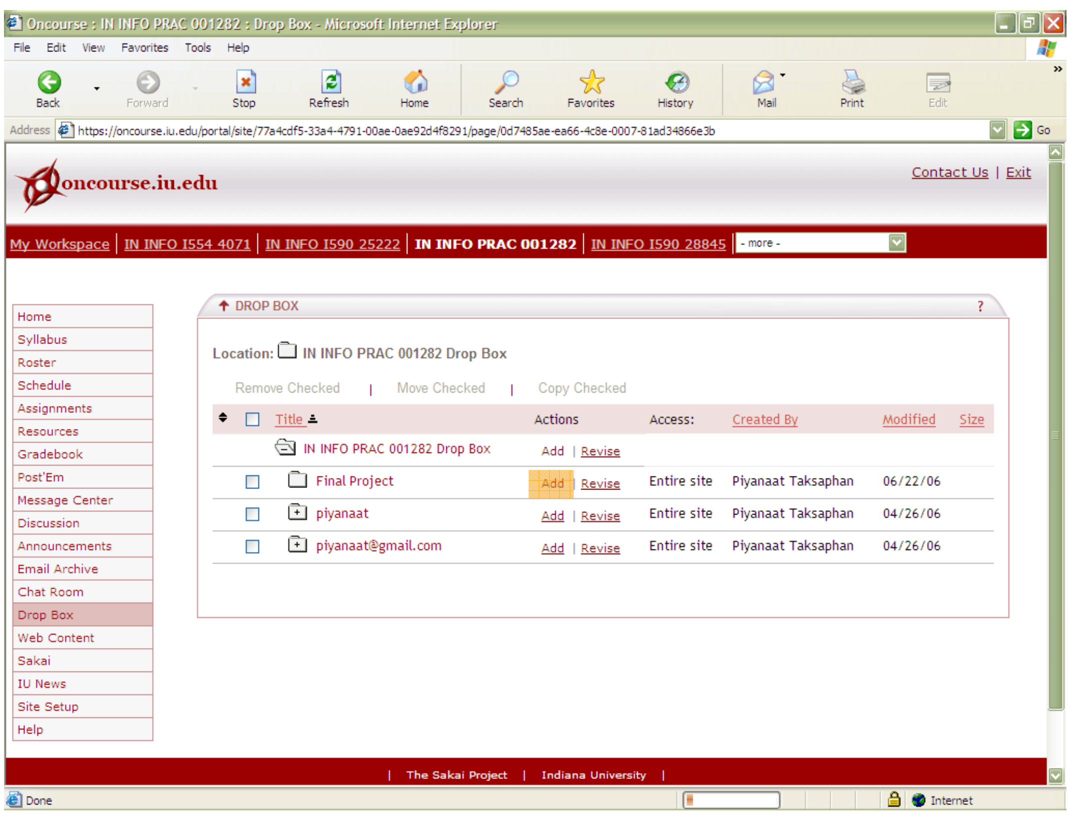


Figure 22: Snapshot of Task 5 - Step 6

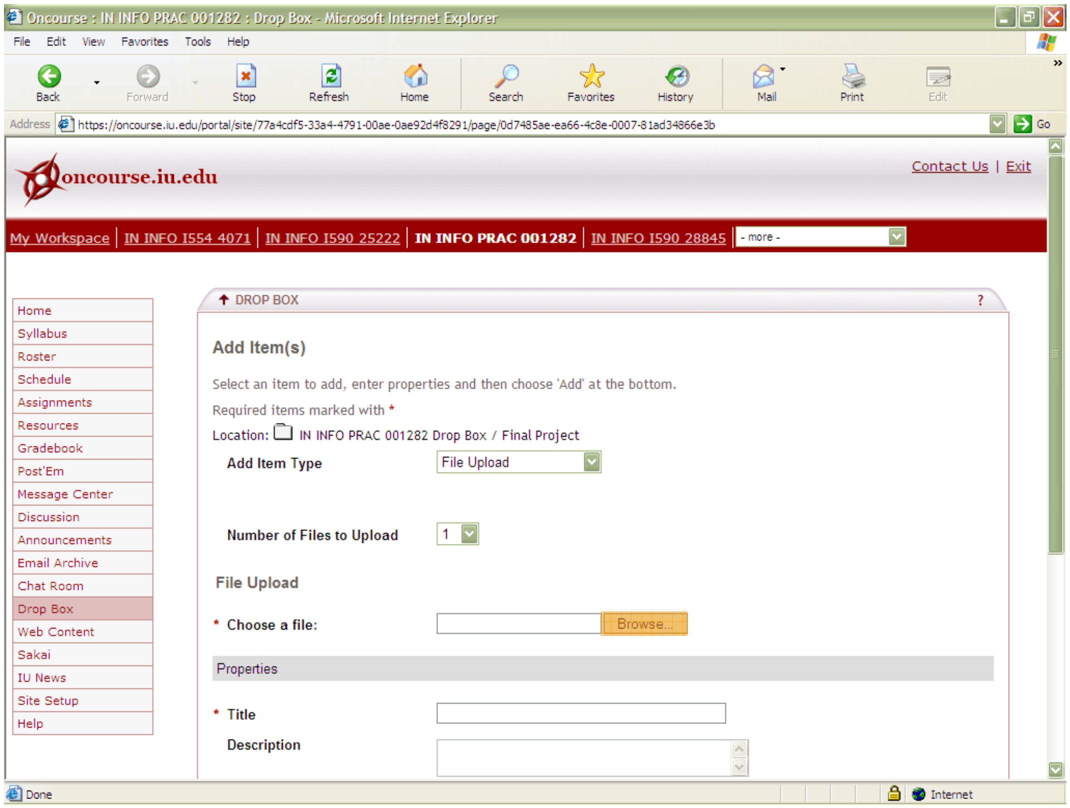


Figure 23: Snapshot of Task 5 - Step 7

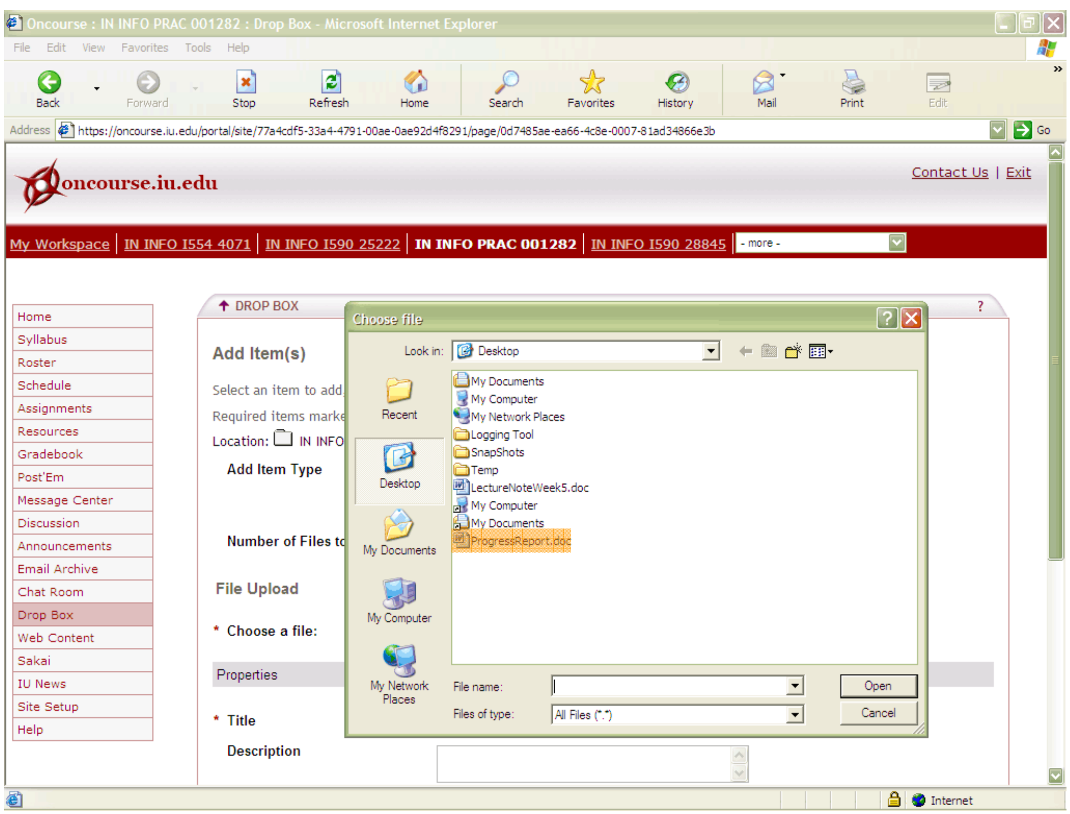


Figure 24: Snapshot of Task 5 - Step 8

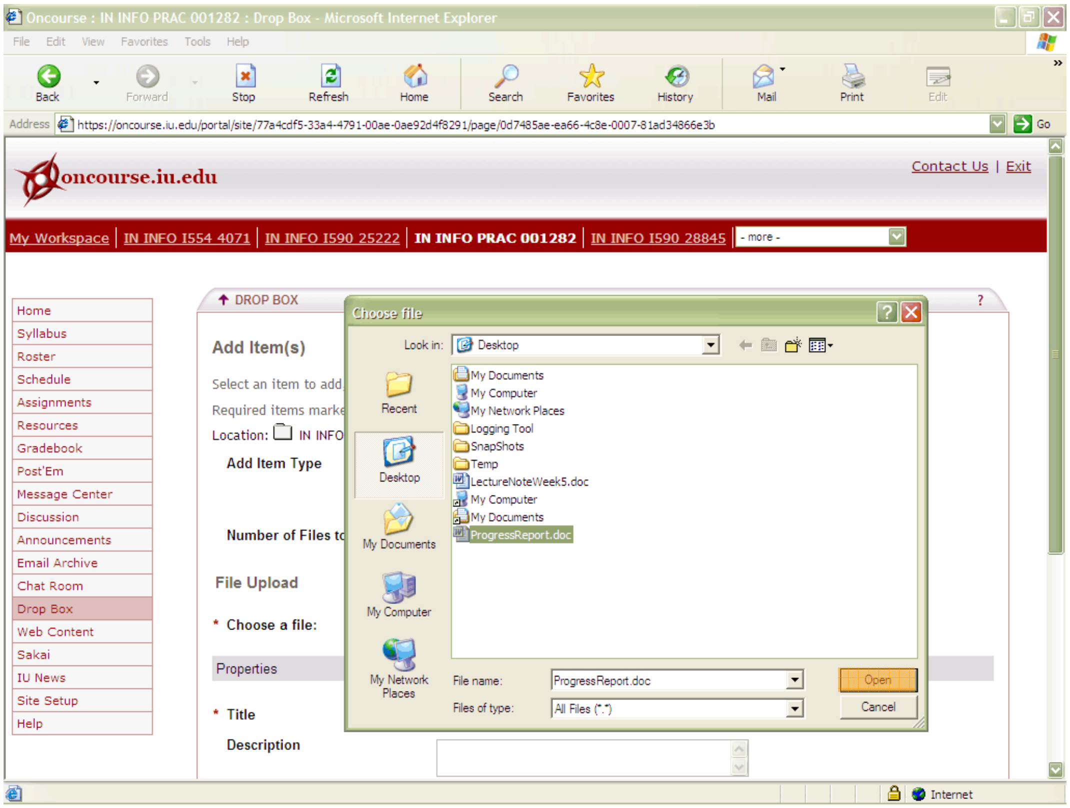


Figure 25: Snapshot of Task 5 - Step 9

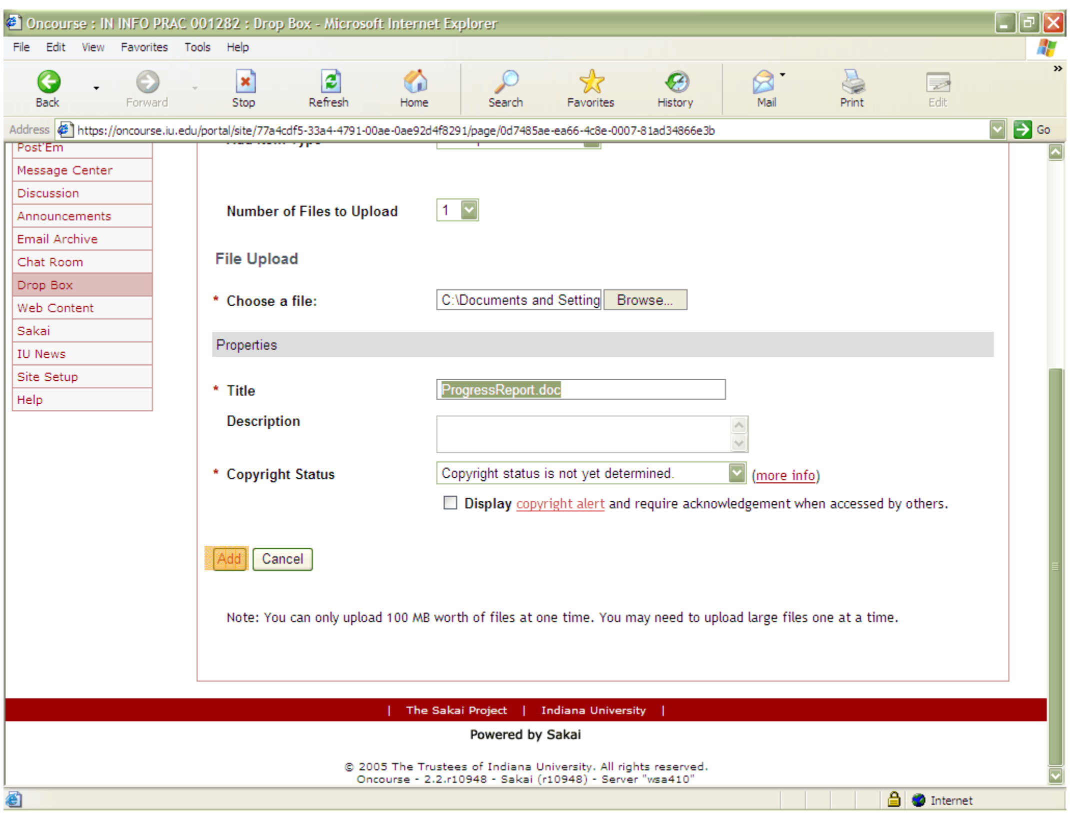


Figure 26: Snapshot of Task 5 - Step 10

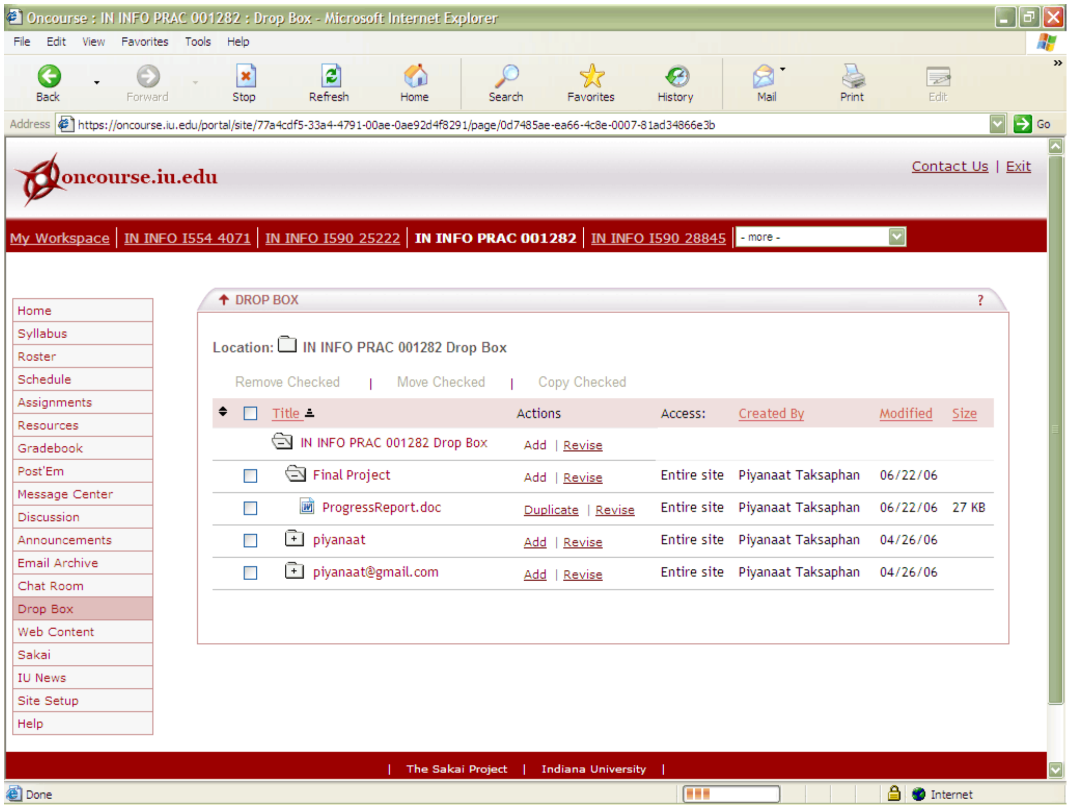


Figure 27: Snapshot of Task 5 – Task Finished

GOMS Modeling

In the next step, interface snapshots were imported into CogTool. Individual screens were linked to form a complete storyboard (see Figure 28). Each task was then translated into a KLM-like language called ACT-Simple. This language is executed via the ACT-R cognitive architecture to produce a performance prediction and a detailed trace of modeled behavior. The expert's time-on-task presented in Figure 29, Figure 30, and Figure 31 were extracted from this ACT-R trace.

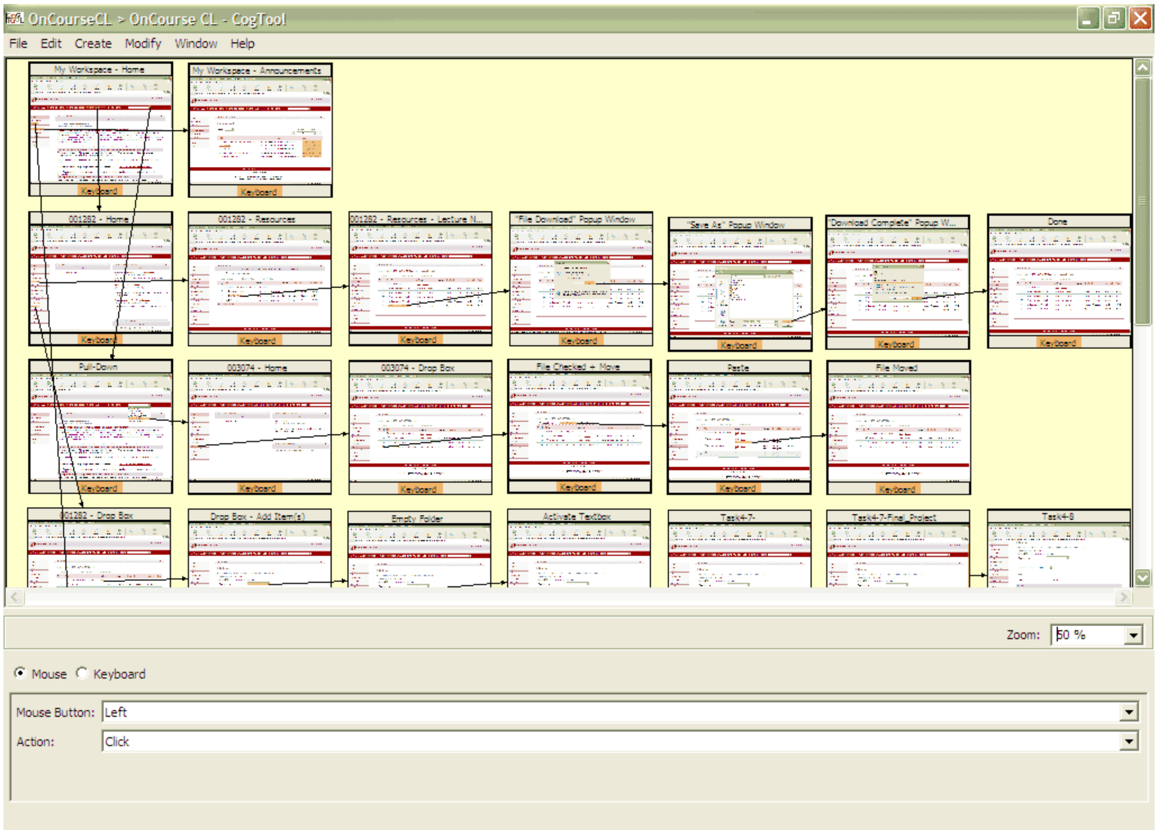


Figure 28: Storyboard

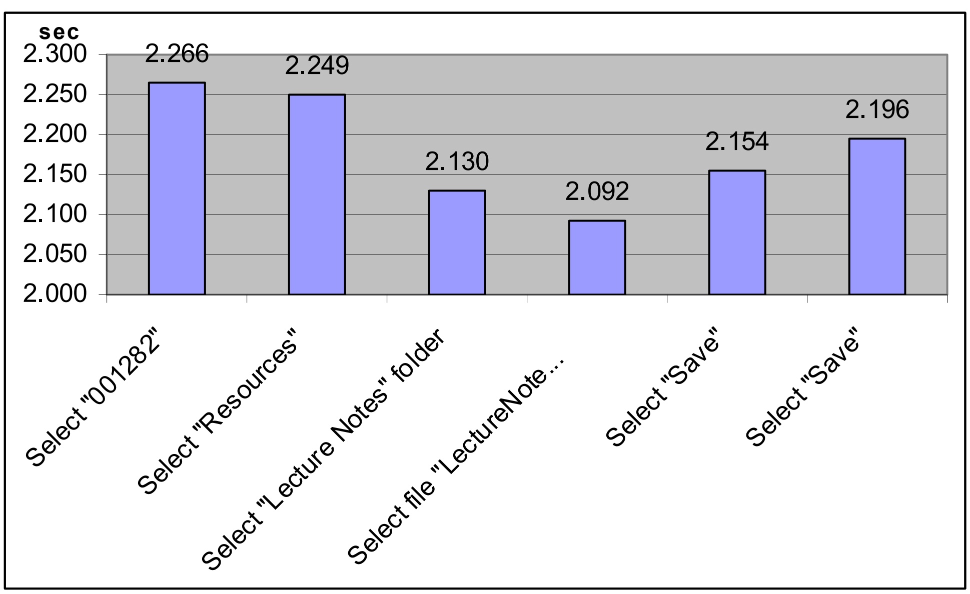


Figure 29: Expert's time-on-task of Task 3

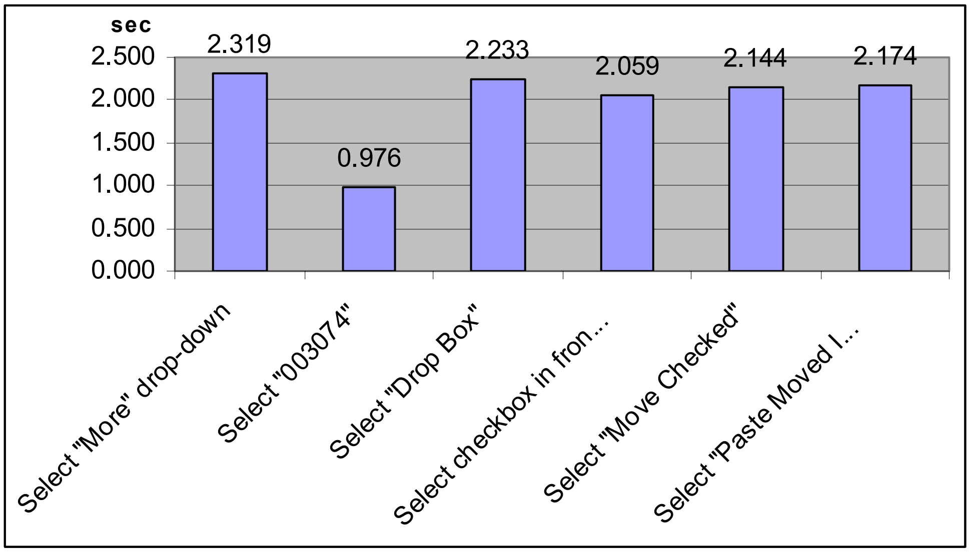


Figure 30: Expert's time-on-task of Task 4

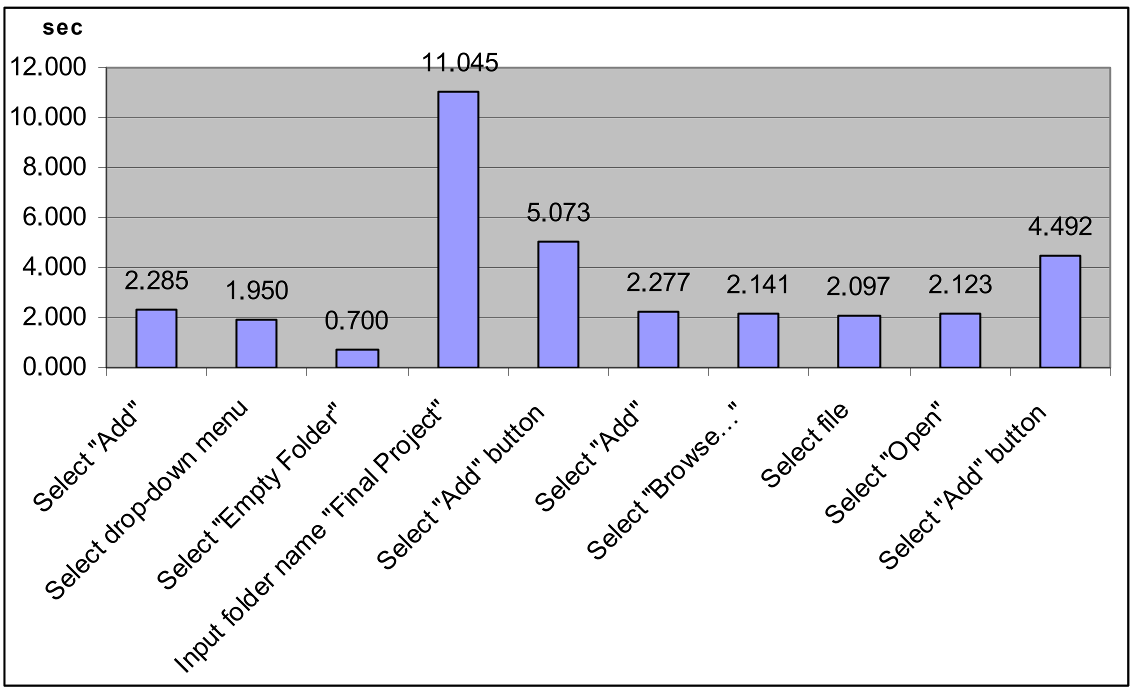


Figure 31: Expert's time-on-task of Task 5

NE Ratios

In calculating the NE ratios of each task, the average novice time-on-tasks were compared to the expert time-on-tasks presented in the previous section. In the experiment, there were some cases in which the participants were not able to finish the tasks because they gave up or because the time was up. The data of these unfinished steps were replaced by the maximum time of that step.

Figure 32 shows the NE Ratios of Task 3. In this task, two participants were not able to finish the task under cognitive load. Two of them gave up before finishing Step 4 (select file "LectureNoteWeek05.doc").

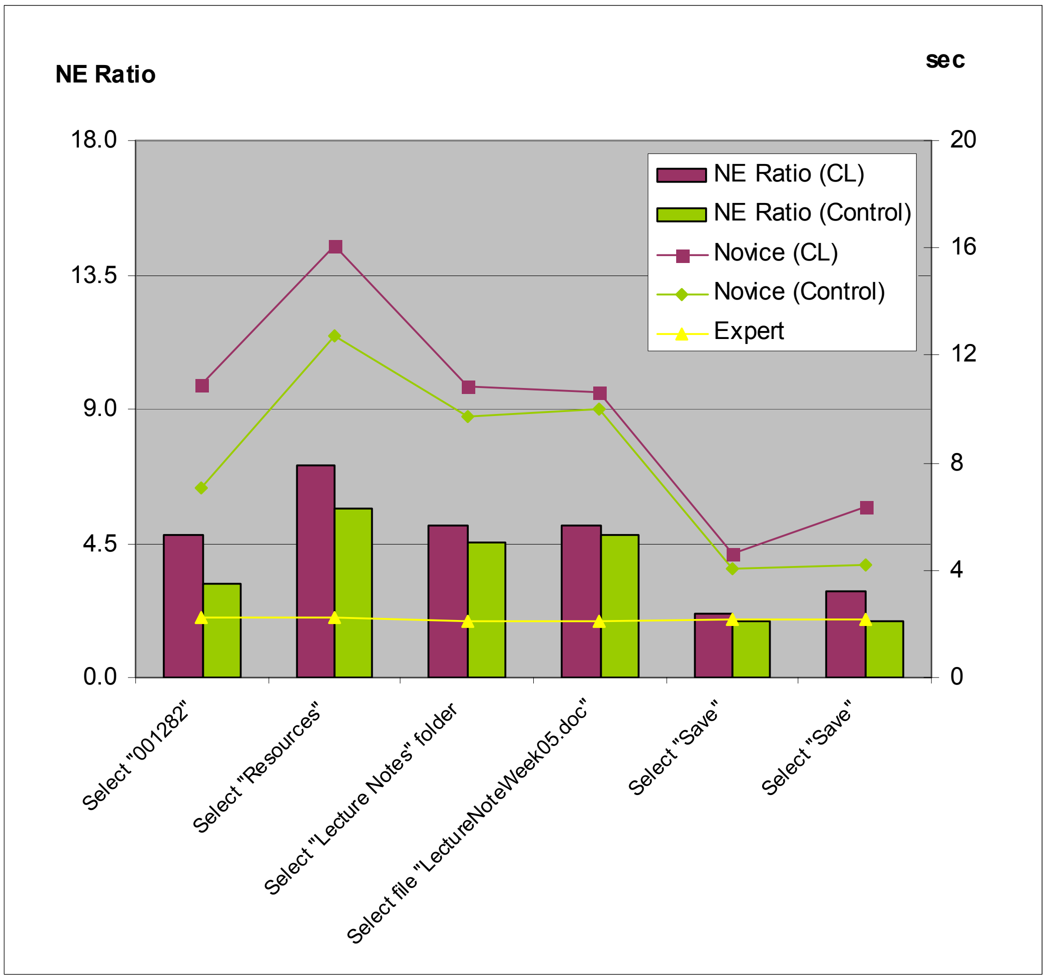


Figure 32: NE Ratios of Task 3 (download file)

Figure 33 shows the average NE Ratio of Task 4. In the control condition, 11 participants were not able to finish the Task; three participants quit before finishing Step 4 (select checkbox in front of "MidtermProject_Comment.doc"), three participants quit before finishing Step 5 (select "Move Checked"), and five participants quit before finishing Step 6 (select "Paste Moved Items"). In the cognitive-load condition, ten participants were not able to finish the Task; four participants quit before finishing Step 4 (select the checkbox in front of "MidtermProject_Comment.doc"), four participants quit before finishing Step 5 (select "Move Checked"), and two participants quit before finishing Step 6 (select "Paste Moved Items").

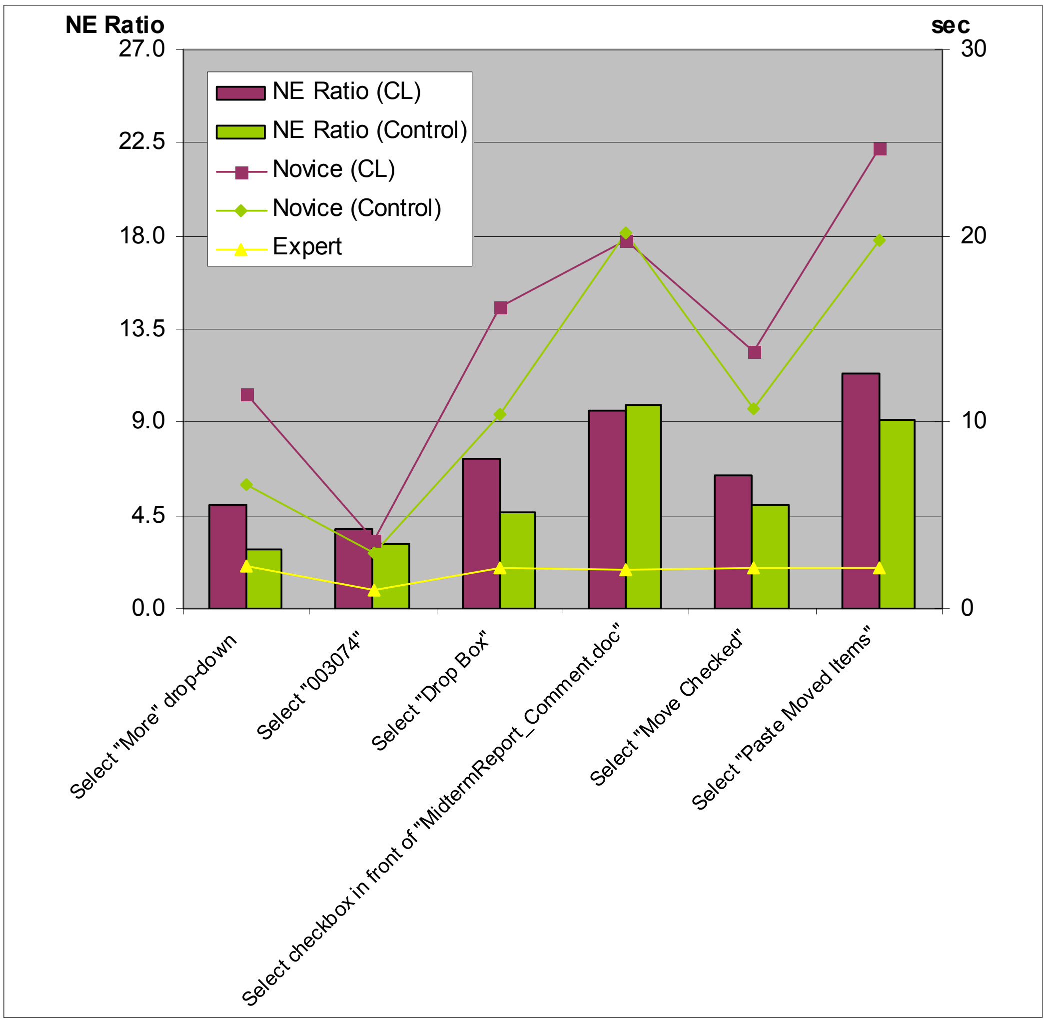


Figure 33: NE Ratios of Task 4 (move file)

Figure 34 shows NE Ratios for Task 5. In the control condition, 12 participants were not able to finish the task; four participants quit before finishing Step 1 (select

"Add"), three participants quit before finishing Step 2 (select drop-down menu), and five participants quit before finishing Step 3 (select "Empty Folder"). In the cognitive-load condition, 11 participants were not able to finish the task; five participants quit before finishing Step 1 (select "Add"), three participants quit before finishing Step 2 (select drop-down menu), and three participants quit before finishing Step 3 (select "Empty Folder").

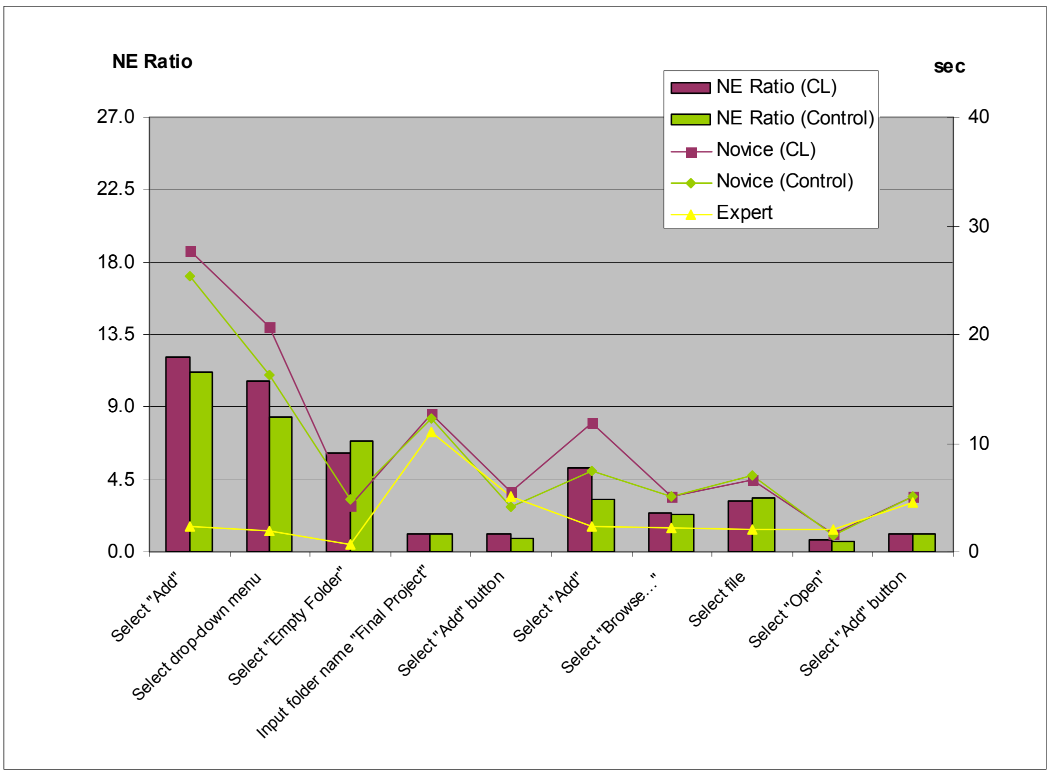


Figure 34: NE Ratios of Task 5 (create folder and upload file)

Repeated ANOVA Analysis

A repeated measure ANOVA was conducted to assess whether there were differences between the average user performance scores measured under two conditions: control condition and cognitive-load condition.

Data from the participants who did not finish the tasks were also included in this analysis. Any steps that the participants did not perform were considered as "high NE ratio" steps:

$$User\ Performance = \frac{Number\ of\ task\ steps\ (S) - NE_{high} - Number\ of\ incomplete\ steps}{Number\ of\ task\ step\ (S)}$$

User performance score was calculated for every participant. As a result, each participant has two user performance scores, one for the control condition, and the other one for the cognitive-load condition. This data was entered in SPSS Version 13 to perform a repeated ANOVA analysis. The results indicated a statistically significant difference between user performance score measured under the two conditions, F = 32.973, p < .000 (see Table 2).

Table 2: Result from repeated ANOVA analysis

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
cog_load	Pillai's Trace	.524	32.973[a]	1.000	30.000	.000
	Wilks' Lambda	.476	32.973[a]	1.000	30.000	.000
	Hotelling's Trace	1.099	32.973[a]	1.000	30.000	.000
	Roy's Largest Root	1.099	32.973[a]	1.000	30.000	.000

a. Exact statistic

b.

Design: Intercept
Within Subjects Design: cog_load

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
cog_load	Sphericity Assumed	.502	1	.502	32.973	.000
	Greenhouse-Geisser	.502	1.000	.502	32.973	.000
	Huynh-Feldt	.502	1.000	.502	32.973	.000
	Lower-bound	.502	1.000	.502	32.973	.000
Error(cog_load)	Sphericity Assumed	.456	30	.015		
	Greenhouse-Geisser	.456	30.000	.015		
	Huynh-Feldt	.456	30.000	.015		
	Lower-bound	.456	30.000	.015		

Correlation Analysis

The correlation analysis was conducted to test whether the subjective ratings of disorientation correlate better with the user performance score under the cognitive-load condition than the user performance score under the control condition. The result shows that the most correlated pair is the user performance score under cognitive load and the statement "It is easy to get lost." (*r* = 0.3753). Although all of the correlations were found to be weak (see Table 3), the user performance score under the cognitive-load condition was found to be more closely correlated with both of the subjective rating scores than the user performance score under the control condition.

Table 3: Correlation Coefficient between User Performance Score under two conditions vs. two subjective rating scores

	I always know where I am in OnCourse.	It is easy to get lost.
Control	-0.1227	0.2467
Cognitive-Load	-0.2418	0.3753

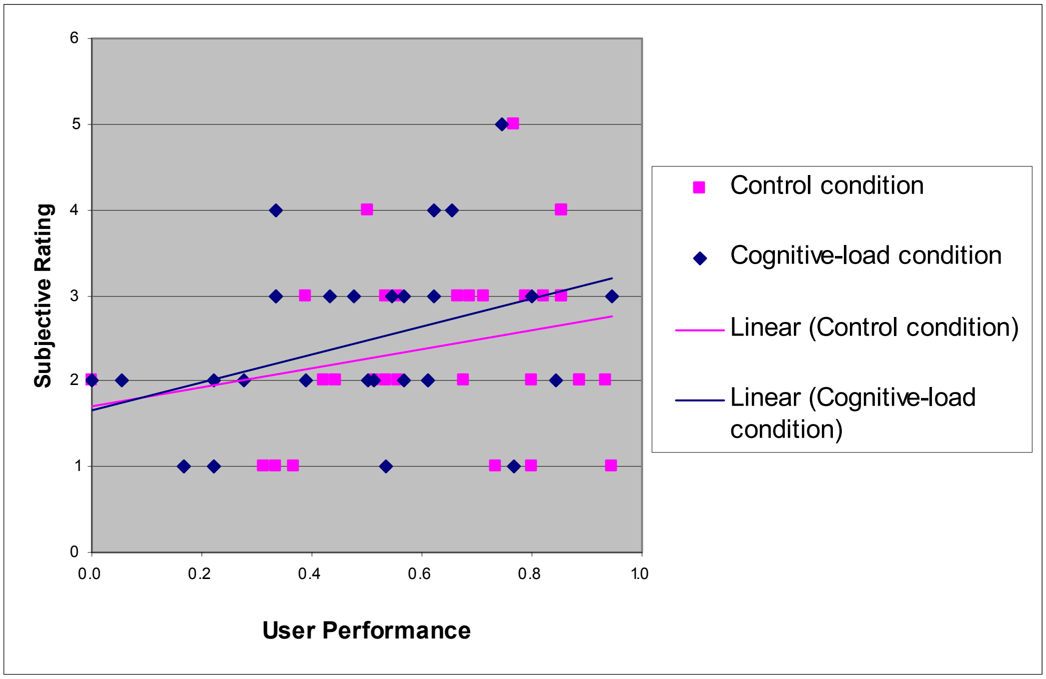


Figure 35: Scatter Plot of the User Performance Score vs. "It is easy to get lost."

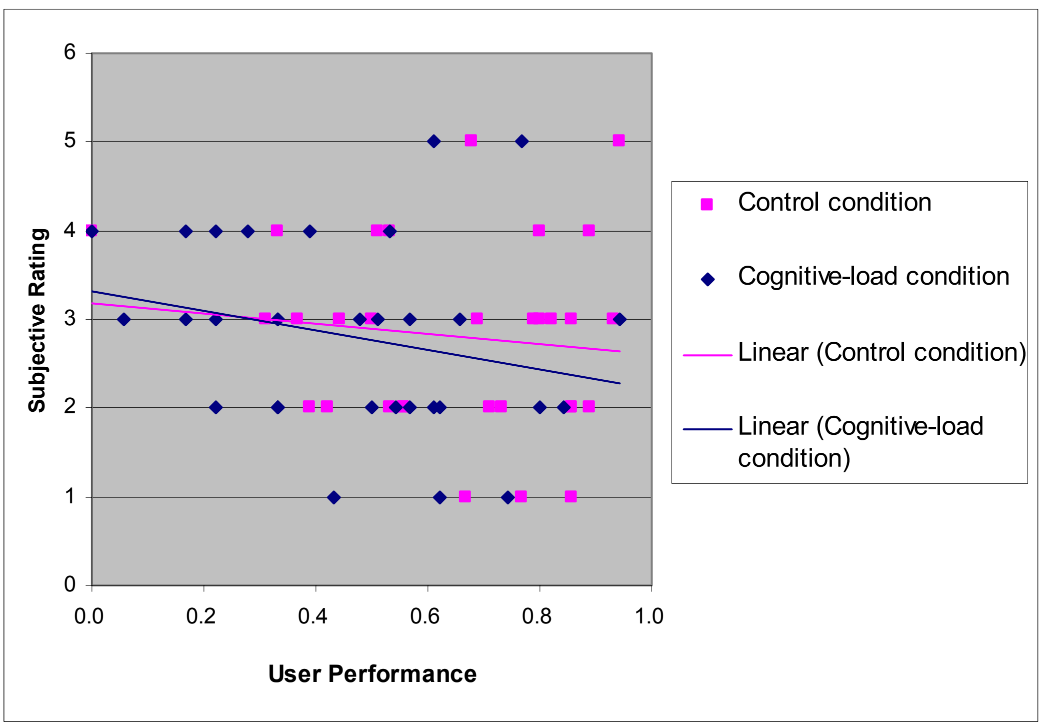


Figure 36: Scatter Plot of the User Performance Score vs. "I always know where I am in OnCourse."

It is also interesting to investigate the correlation between the users' performance score and their recall score. However, the result reveals only a weak correlation between them (r = 0.1720 for the control condition, and r = 0.1404 for the cognitive-load condition).

Table 4: Correlation Coefficient between User Performance Score vs. Recall Score

	Recall Scores
Control	0.1720
Cognitive-Load	0.1404

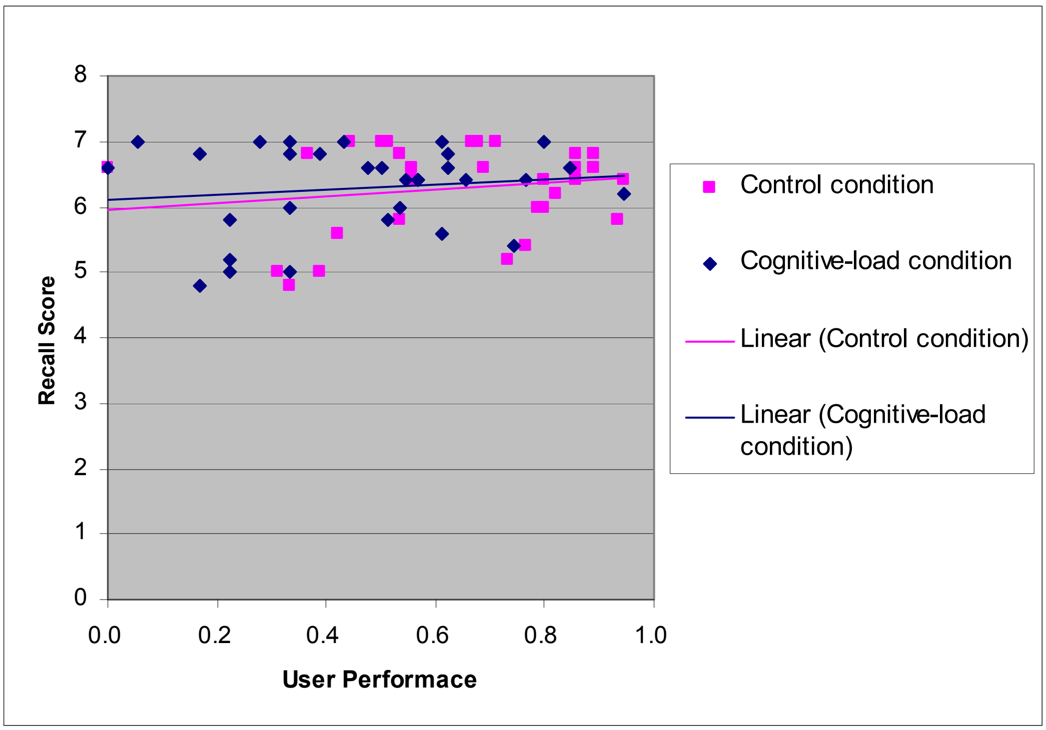


Figure 37: Scatter Plot of the User Performance Score vs. Recall Score

Error Patterns

From the experiment, 90 error occurrences were observed. Thirty-two were observed in the control setting, and 58 were observed in the cognitive-load setting.

Although there were some individual differences in user performance, the most common error observed during the experiment sessions is that the users were unable to find specific features to perform the intended action. This includes failure to find facilities for moving, pasting, and adding an empty folder. This type of error was observed in both experimental conditions.

In addition to those common errors, some error patterns happen specifically in the cognitive-load condition. These are indications of the users' high cognitive-load. Based on the researcher's analysis, out of these 90 error occurrences, 11 error patterns were identified. Three patterns were identified in cognitive-load setting only, and eight were identified in both settings.

Errors	Control Condition	Cognitive-load Condition
1. Failure/difficulty in locating 003074 class	4	8
2. Failure/difficulty in locating facilities for moving	3	7
3. Failure/difficulty in locating facilities for pasting	6	10
4. Users tried to use "Back" button on the browser to reset/undo/restart their previous actions.	3	7
5. Users tried to use "Drop Box" link to go to the Drop Box's home page (to reset/undo/restart their actions).	2	2
6. Rejecting "Add" function (did not expect to find a creating folder in "Add")	5	7
7. Failure/difficulty in locating facilities for locating "Empty Folder"	8	9
8. Users did not realize that the file was already moved/pasted in the folder.	1	1
9. Users copied file instead of moved file.	-	3
10. Users created a new folder and uploaded a file at the same time using "File Upload" function.	-	6
11. Users forgot what they were trying to do.	-	5

CHAPTER FIVE: DISCUSSION

User Performance Score

Overall, the NE ratios in the cognitive-load condition were found to be higher than the NE ratios in the control condition. In other words, users took more time to complete each step under the cognitive-load condition than they did under the control condition. From the ANOVA analysis, it was found that the difference between the user performance scores in the two experimental conditions was statistically significant. The user performance score from the cognitive-load condition was found to correlate more with both user subjective ratings of disorientation than the user performance score from the control condition. The highest correlation score exists between the user performance score under the cognitive-load condition and the subjective rating of "It is easy to get lost."

From the investigation during the experiment, it was observed that users tried to use the browser's "back" button to go back to the previous page they visited, or to undo an action. However, the back button did not work as the users expected. After the back button failed, the users often tried to click on the tool link (Resources or Drop Box), expecting it to bring them to the homepage of the tool and refresh any mistakes they wanted to undo. However, these links did not work as expected. From the post-test interview, many participants reported feeling disoriented because of these unexpected behaviors. This showed that the users' mental model was incorrect. Their mental models were based on their previous knowledge. When the system did not react as they expected, confusion and disorientation resulted.

Error Patterns

A higher number of error occurrences was observed in the cognitive-load condition than in the control condition. This is consistent with the result of the study of Olson and Olson (1990) that showed the higher frequency of errors with a heavier cognitive workload. The researcher's analysis identified 11 eleven error patterns from these occurrences, eight of which occurred in both settings. The most common error is a failure or difficulty in finding specific features to perform the intended action. This includes failure to find facilities for moving, pasting, and adding an empty folder. Three out of 11 patterns occurred in the cognitive-load condition. They might indicate the high cognitive-load condition of the users. According to Norman's error classification, as cited in Lindmark (2000), these three patterns fall into a category of Description Errors, Errors Resulting from Unintentional Activation of Schemas, and Errors Resulting from Loss of Schemas Activation.

Description Errors

According to Norman (1981) as cited in Lindmark (2000), this error pattern occurs when the intended action and the erroneous one have similar descriptions. The performed action is often closely related to the desired one.

In Task 4, five participants copied and pasted the file instead of moving and pasting it. After they found out that it was a copy function, they deleted the original file.

Errors Resulting from Unintentional Activation of Schemas

Norman (1981), as cited in Lindmark (2000), describes these errors as incidents when schemas that are not part of a current action sequence become activated for extraneous reasons, then lead to slips.

Task 5 was to create an empty folder and upload a file into it. This task has two sub-goals: creating a new folder and uploading a file. It was observed that four participants tried to create a new folder using the "File Upload" function, because a "Title" box is placed next to a "Choose a file" box in the File Upload page. When the participants saw a "Choose a file" box, they automatically browsed for a file. Similarly, when the participants spotted the "Title:" box, they automatically entered the folder name. Norman (1981) explained this as a data-driven error.

Errors Resulting from Loss of Schemas Activation

Norman (1981), as cited in Lindmark (2000), explained that this error category is caused by schemas losing. The user starts to do something, but forgets what the intention was.

This type of error frequently occurred when the participants tried to rehearse the table of letters in the middle of the task sequence. This might be why the participants forgot what they were doing and why they were on that page.

The next section will explain how the findings of this study, including user performance score and error patterns, answer the research questions and hypothesis.

Summary of Research Issues

The first question, *Do measurements of the performance of novice users of OnCourse CL, under cognitive load, provide a better metric than those under controlled observation and, if so, in what way are the measurements better?*, has been answered by evidence that a higher number of error occurrences was observed in the cognitive-load condition (58 occurrences) than in the control condition (32 occurrences). This shows that measurements of the performance of novice users of OnCourse CL, under cognitive load, provide a better metric than those under controlled observation. Some errors might not be emphasized if the usability testing is conducted under laboratory-like conditions. In contrast, artificially increasing the cognitive load can enhance the ecological validity of a usability experiment.

This study has successfully proven the hypothesis: *Subjective measures of disorientation correlate better with user performance scores under cognitive load than under controlled observation.* The results from the correlation analysis have shown that the user performance scores from the cognitive load condition correlate more with both user subjective ratings of disorientation than the user performance score from the control condition (r = -0.2418 vs. -0.1227 for the statement "I always know where I am in OnCourse." and r = 0.3753 vs. 0.2467 for the statement "It is easy to get lost."). This finding also answers the first research question by showing that measuring novice users' performance under cognitive load can replicate a degree of disorientation that is closer to what users subjectively estimate that they feel in a real situation.

The second research question, *How does cognitive load influence the error patterns of novice users of OnCourse CL?*, has been answered by findings that 3 out of

11 patterns occurred specifically in the cognitive-load condition. These patterns are copying instead of moving a file, creating a new folder and uploading a file at the same time using "File Upload" function, and forgetting what they were trying to do. According to Norman (1981), these patterns fall into a category of Description Errors, Errors Resulting from Unintentional Activation of Schemas, and Errors Resulting from Loss of Schemas Activation. To sum up, usability testing with cognitive load revealed some error patterns that had not appeared without cognitive load.

Finally, this research has provided design recommendations to answer the last research question, *From the error patterns found in the experiment, what design recommendations would help learning portal designers' to create usable learning portals?*. The next section will explain these design recommendations in detail.

Design Recommendations

From the error patterns found in this study, the recommendations for fixing these problems are as follows. They are categorized according to Nielsen's severity rating.[6]

Usability catastrophe problems

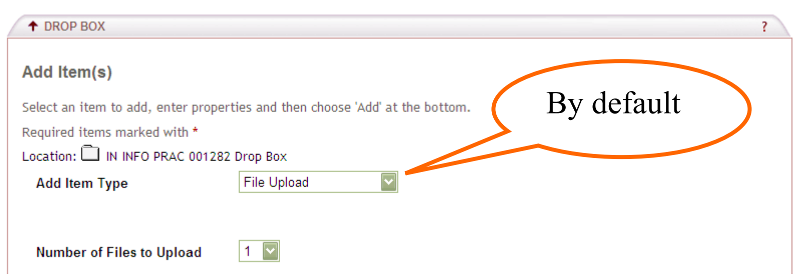
Problem	**Users could not locate facilities for moving easily.**
Explanation	To move a file(s) or a folder(s), first the user has to select the checkbox in front of the objects he/she want to move. Then, the "Move Checked" (as well as the "Remove Checked" and the "Copy Checked") buttons will be active.
Observations	The button looks inactivated for the users. Even when they

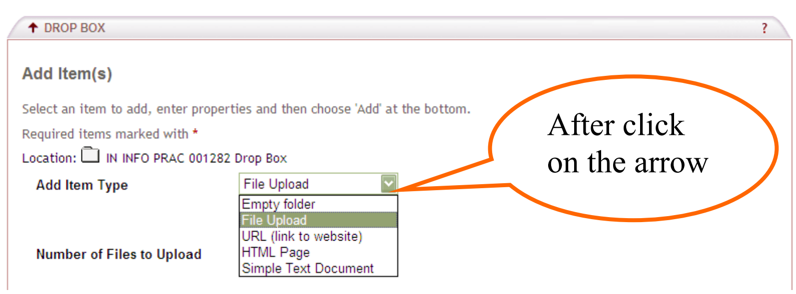
[6] http://www.useit.com/papers/heuristic/severityrating.html

	already check the checkbox in front of a file. When the users move the mouse pointer over the buttons, they expected to see a hand-shape pointer. However, the pointer shape is still an arrow. As a result, the users thought that it is still not clickable.
Recommendation	Change the mouse-over shape of the pointer to a hand.

Problem	**Users could not locate facilities for pasting easily.**
Explanation	A link "Paste Moved Items" is available in the Actions column after the users already clicked "Move Checked" button.
Observations	There are also "Add" and "Revise" in the Actions column. These links are always available and there is too much text on the interface so that when the "Paste Moved Items" appears on the interface, the users did not notice it. Moreover, the location of the link is not where the users expected. They looked at the top row where the "Move Checked" button is placed.
Recommendation	Change the "Move Checked" button to a drop-down menu with destination folders listed inside so that after the users click move, they can select the destination folder immediately.

Problem	**Users could not find facilities for creating a new folder easily.**
Explanation	To create a new folder, the users have to click on the "Add" link to go to the "Add Item(s)" page, then select "Empty Folder" from the drop-down list.
Observations	Many participants reported that they did see the "Add" link but did not think it was relevant, so that they ignored it. Although most of the participants got as far as the "Add Item(s)" page, they still could not find the "Empty Folder" on the drop-down list. They explained that because the "File Upload" is highlighted by default, they read from that highlighted line down until the last item in the list. That is why they did not notice that there is "Empty Folder" placed above the "File Upload."

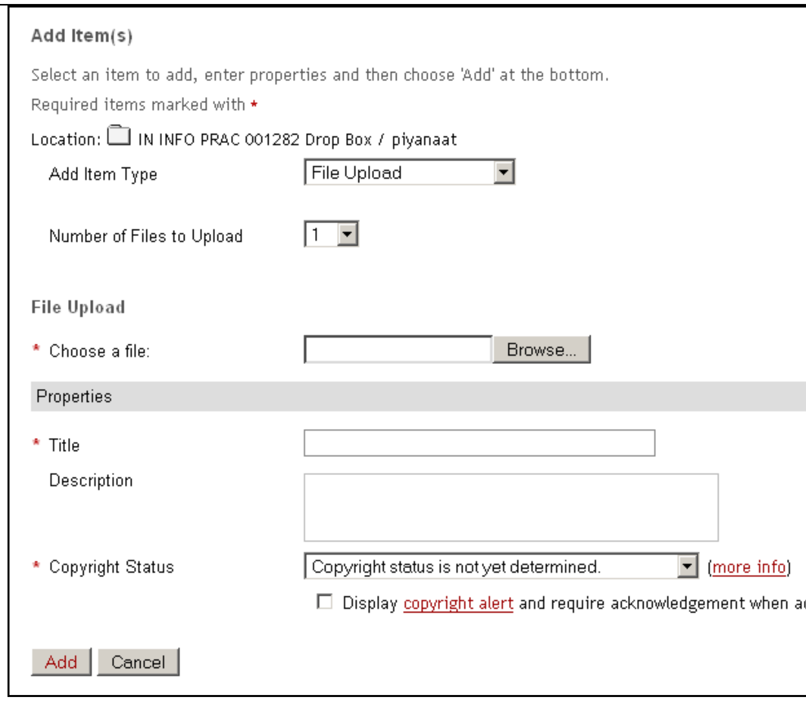




Recommendation	• Place “Empty Folder” down under “File Upload” • Move the drop-down menu to the front page and rename it to “Add new item(s)” or “Add new…” and place it at the same location as “Remove Checked,” “Move Checked,” and “Copy Checked” because that is the location the users expected to find it.

Major usability problems

Problem	**Users created a new folder and uploaded a file at the same time using the “File Upload” function.**
Explanation	The “Add Item(s)” page displays the “File Upload” function by default. To create a new folder the users have to select “Empty Folder” from the drop-down list first, then enter the title of the folder, and click “Add.”
Observations	The highlight on the “Properties” line is more prominent than the heading “File Upload,” “Folder,” or “Access.” As a result, what users see is not what the designer intended to. The page seems to be separated into Add Items and Properties instead of Add Items and File Upload.

	 When the users saw "Choose a file," they selected a file to upload. Below the "Choose a file" line, is a Properties line which is intended to be properties of the file. However, the highlight makes it looks like it starts a new section. So, when users saw the next line saying "Title" they thought that they were supposed to enter the name of a folder they wanted to put the file in.
Recommendation	Make the Add Item(s) and File Upload heading more prominent than the Properties one. It can also be simplified by removing unnecessary items from the interface. For uploading a file, the "Title" might not necessary.

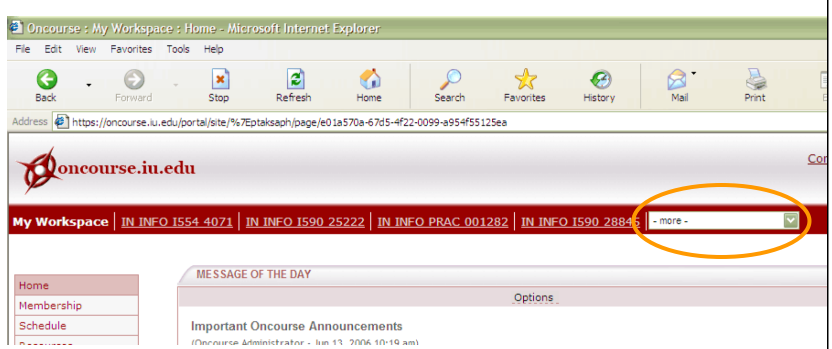
Problem	**“Drop Box” links (as well as other tools’ link) do not bring users to its front page as they expected.**
Explanation	The first time the users click the Drop Box link, it brings them to Drop Box’s front page. If they are already in any folder inside Drop Box, the link refreshes the page but goes nowhere. If the users leave the Drop Box tool and go somewhere else, when they come back to Drop Box, the interface shows the page they visited before they leave.
Observations	Whenever the users clicked on the Drop Box link, they expected it to take them to the front page of Drop Box. If they left the Drop Box tool and went somewhere else, when they came back to Drop Box, the interface displayed the page they had visited before they left. The users did not remember where they had been, so they did not recognize the page. They were confused by not seeing the front page.
Recommendation	It should be more consistent. The same link should bring the users to the same place. The “Drop Box” link should bring the users to its front page every time. Otherwise, in case that the users are already in Drop Box, the link should be disabled.

Problem	**The browser back button does not work.**
Explanation	Generally users use the browser’s back button to return to the previous pages.

Observations	The browser's back button is disabled and it does not bring users to the previous pages like they expected. The breadcrumb navigation trail is available but somehow is not working properly. When the users go 3-4 levels deep, the breadcrumb does not keep track of the upper levels.
Recommendation	If the back button must be disabled, the breadcrumb should be working properly.

<u>Minor usability problems</u>

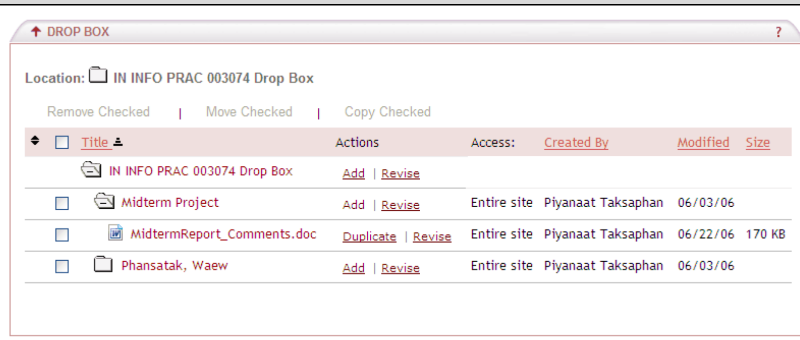
<table>
<tr><th>Problem</th><th>Users could not locate 003074 class easily.</th></tr>
<tr><td>Explanation</td><td>The courses are listed as horizontal tabs on the OnCourse CL's home page. When they exceed the space limit, some of them are placed in the drop-down list with the word "- more -."



The visibility and order of the courses shown in these tabs can be customized in "Preferences" > "Customize Tabs." Users can set any courses they do not want to show as "Sites not visible in Tabs." They can also rearrange the order of the courses.</td></tr>
</table>

Observations	• Two participants stated that the word "More" sounds like there are more "Functions" in the drop-down list. They did not know that it means more "Courses." • After showing the participants that the courses are listed alphabetically, nine participants said that they prefer courses to be listed by semester as they had been in the original OnCourse. • When showing them the function to customize these tabs, almost all the users said that the function is too hard to find and they probably would not know that it exists.
Recommendation	The tabs should, by default, show the courses a student is currently taking. Courses from previous semesters should be listed by semester inside a drop-down list with a label "Previous Semester" instead of "- more -."

Cosmetic Problems

Problem	**Users did not notice that the file had already been moved (pasted) into the folder.**
Explanation	

Observations	Users did not recognize the different levels of files and folders.
Recommendation	Make the different level of files/folders more distinguishable (increase the indent).

Limitations of the Study and Recommendations for Further Research

Due to time and budget constraints, this study consisted of a single experiment. Although each participant performed the same task twice, the conditions under which they performed the tasks varied. The results from this experiment could not reflect a learning curve of the novice users of the system. It is possible that the users will become familiar with the system over time. Thus, the cost of this learning may outweigh the costs of redesigning. A long-term study should be conducted to reveal novice users' learning curve.

In addition, the experiment in this research focused only on the file manager tools of OnCourse CL, which are Resources and Drop Box. The researcher intended the findings of this study to benefit Indiana University. However, many more features were not investigated in this study. It would be a contribution to the IU community if future researchers could extend this work by focusing on other commonly-used tools on OnCourse CL, such as Assignments and Announcements.

CHAPTER SIX: CONCLUSION

Summary of Research Findings

This research study has investigated how cognitive limitations affect users. The users' performance score and error patterns from the cognitive-load condition were compared with those from the control condition. The results of this study have shown that cognitive load affects users' task performance. The user performance score under the cognitive-load condition proved to be significantly different from the control condition ($F = 32.937$, $p < .000$). The user performance score under the cognitive-load condition was correlated better with both of the subjective rating scores than the user performance score under the control condition ($r = -0.2418$ vs. -0.1227 for the statement "I always know where I am in OnCourse." and $r = 0.3753$ vs. 0.2467 for the statement "It is easy to get lost."). The most correlated pair is the user performance score under cognitive load and the statement "It is easy to get lost." ($r = 0.3753$). Moreover, testing users under cognitive load yields higher error frequency than testing users under the control setting (58 vs. 32 occurrences). Specifically, three out of eleven error patterns could be revealed only under the cognitive-load condition. These error patterns were copying instead of moving files, creating a new folder, and uploading a file at the same time using "File Upload" function, and forgetting what they were trying to do. These error patterns fell into Norman's error category of Description Errors, Errors Resulting from Unintentional Activation of Schemas, and Errors Resulting from Loss of Schemas Activation, respectively.

These findings suggest that it is necessary to simulate a cognitive-load situation when conducting a usability evaluation to mimic users' real situation. Examples of such situations are a dynamic workplace, an environment of a portable device, and a collaborative learning environment which was investigated in this study. These environments have situational variability such as cognitive-load, distraction, time-pressure, and task-switching that affects the user's cognitive resource limitations. A laboratory setting cannot replicate the error patterns that occur in real life situations.

Summary of Contributions

This research study has made three contributions to the field of Human-Computer Interaction (HCI) and to research on collaborative learning portals:

(1) The practical contribution: This thesis identifies some of the problems with OnCourse CL, based on the findings from an empirical experiment, and provides recommendations on how to fix them.

(2) A theoretical contribution: The thesis shows the benefits of artificially increasing cognitive load to enhance the ecological validity of a usability experiment conducted using the Novice-Expert ratio Method. A common assumption in HCI work is that the higher the correlation between a particular objective performance metric and a user's subjective rating of performance, the greater the construct validity of the objective performance metric, because both the metric and the subjective rating are affected by the same interface design and human cognitive constraints. Ultimately, they are intended to measure the same thing: the system's usability. Thus, the fact that such subjective ratings as the feeling of being lost were more highly correlated with the NEM user performance score with cognitive load than without cognitive load demonstrates the usefulness of cognitive load to enhance construct validity based on purely statistical grounds. This was supported by analysis of the users'

error patterns: NEM plus cognitive load revealed some error patterns that had not appeared without cognitive load.

(3) A second theoretical contribution: This thesis extends the Novice-Expert ratio Method (NEM) to tasks that have subtasks that some participants are unable to complete. This research study has proposed revising the method of calculating NE ratio to account for the data from participants who did not finish the task. The data of the first unfinished step were replaced by the maximum time allowed for one step, which is 18 * expert-time-on-step. Any steps that took longer than the maximum time were replaced by the maximum time. The steps following the first unfinished step were excluded from the calculation. All incomplete steps were considered as steps with a high NE ratio. As a result, the revised equation takes off those incomplete steps in addition to the steps with a high NE ratio.

$$User\ Performance = \frac{Number\ of\ task\ steps\ (S) - NE_{high} - Number\ of\ incomplete\ steps}{Number\ of\ task\ step\ (S)}$$

Finally, this thesis has successfully confirmed the advantages of collecting time-on-step data instead of only collecting time-on-task data. By collecting novice users' time-on-step and comparing them to those of the expert users', the steps that users are having difficulty with can be identified easily. This way, parts of the OnCourse CL interface that are causing usability problems are emphasized and the degree of severity is presented via the ratio of the novices' time and the experts' time.

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APPENDICES

Appendix A: Pre-Test Questionnaire (for Phase 1)

Participant No. __________________ Date: __________________

General Information

1. Age

   ☐ <18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ >65

2. Gender

   ☐ Male ☐ Female

3. Occupation

   ☐ Undergraduate student

   Please specify: ☐ 1st year ☐ 2nd year ☐ 3rd year ☐ 4th year

   ☐ Graduate student

   ☐ Faculty member

   ☐ Other (please specify)_____________________

Computer and Internet Experience

What kind of operating system do you use? ☐ Microsoft Windows ☐ Apple Macintosh OS

What kind of Web browser do you use? ☐ Internet Explorer ☐ Mozilla Firefox ☐ Opera

☐ Other (please specify) ____________________

How long have you been using computers (years)? ______________

How many hours each day do you use a computer? ______________

How long have you been using the Internet (years)? ______________

How many hours each day do you use the Internet? ______________

OnCourse CL Experience

How long have you been using OnCourse (years)? __________________

How many times each day do you access OnCourse? __________________

How long do you spend each time on OnCourse (minutes)? __________________

Where do you usually access OnCourse from? (check all that apply)

☐ Home ☐ Computer Lab ☐ Work place ☐ Other (please specify) _______________

Appendix B: Usability Test Script (for Phase 2)

Hi, my name is Piyanaat Taksaphan, and I am collecting data for my Thesis about the usability of learning portals. Thank you for your time. I would like to cover a few points with you before you begin this usability test of the portal.

1. **Your role today is as an OnCourse CL portal user. You are NOT being tested, but rather the portal interface you will review is what is under examination.**
2. **Your input will greatly help me make a better decision as to the design of the learning portals.**
3. **The testing process will consist of three parts:**
    a) Two series of 5 tasks focusing on portal manipulation and navigation. In one series, you will be presented with a 3x3 table randomly filled with 7 letters. Please remember this table as much as possible while performing the tasks. After finishing the task, you are to fill out the table as accurately as possible. You will have approximately 5 minutes to complete each task. However, this should be more than enough time. In the event you go over the allotted time I will ask you to move on to the next task.
    b) A post-task questionnaire, which will provide some background about your experience as a computer and the Internet user.
    c) A post-task interview, which will ask you a range of questions related to your experience with the learning portal you just reviewed.
4. **Regarding the Tasks:**
    a. You will be allowed to read each of the task descriptions before you begin. This will allow you time to completely understand what each task is asking you to do.
    b. Please feel free to ask if anything is unclear. If once you begin and the task still seems unclear, you may ask whatever is needed.
    c. During the process of carrying out each task, I ask if you could speak aloud what you are thinking or feeling.
        i. In other words feel free to verbalize any problems, i.e. frustrations, disturbances, or lack of clarity in anything you see during the process.
        ii. You may also express any positive comments if you feel it is necessary.
        iii. You don't need to be excessive, but rather very natural in verbally expressing what you would normally keep in your head.
    d. Please, do not feel pressured as if you were under a time limitation to complete each task, but rather simply read the task and carry it out as quickly as possible.
5. **During the task period, I will record the time for completing each task and take note on your comments and expression. The computer screen will be recorded. There will be no audio or video recording at any time.**
6. **The data collected today is for my thesis study only. No data that can be used to identify you as an individual will be collected. And you can quit the test any time if you feel not comfortable doing the test.**
7. **I deeply appreciate your cooperation in the learning portal service evaluation.**
8. **Are there any questions?**
9. **So, let's get started.**

Appendix C: Task Record Sheet (for Phase 2)

Participant No. ___________________ Date: ___________________

Conditions: ☐ O (without cognitive load) ☐ X (with cognitive load)

		Notes
Task 1	Task completed: Yes or No	
	Comments on observed behavior.	
Task 2	Task completed: Yes or No	
	Comments on observed behavior.	
Task 3	Task completed: Yes or No	
	Comments on observed behavior.	

Task 4	Task completed: Yes or No	
	Comments on observed behavior.	
Task 5	Task completed: Yes or No	
	Comments on observed behavior.	

Appendix D: Task Description Sheets (for Phase 2)

TASK NO.	TASK DESCRIPTION
1	Check if there are any new announcements from any of your classes today.

TASK NO.	TASK DESCRIPTION
2	Your teammate wants to set up a group meeting on Wednesday, June 28th, 2006 at 2pm. Check your schedule to see if you are available at that time.

TASK NO.	TASK DESCRIPTION
3	In the **IN INFO PRAC 001282** class's Resources tool, download the file named "LectureNoteWeek5.doc" inside the folder named "Lecture Notes" to your desktop.

TASK NO.	TASK DESCRIPTION
4	In the **IN INFO PRAC 003074** class's Drop Box, move the "MidtermReport_Comments.doc" file to "Midterm Project" folder.

TASK NO.	TASK DESCRIPTION
5	There is a file named “ProgressReport.doc” on the desktop. In your **IN INFO PRAC 001282** class’s Drop Box, create a new folder called “Final Project”, and then place the file into this folder.

Appendix E: Tasks order (for Phase 2)

Participant no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Condition	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O
Task order ↓	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3	4
	4	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3
	5	4	3	3	4	5	5	4	3	3	4	5	5	4	3	3	4	5
Condition	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X
Task order ↓	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3	4
	4	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3
	5	4	3	3	4	5	5	4	3	3	4	5	5	4	3	3	4	5

Participant no.	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Condition	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O
Task order ↓	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3	4
	4	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3
	5	4	3	3	4	5	5	4	3	3	4	5	5	4	3	3	4	5
Condition	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X
Task order ↓	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3	4
	4	3	5	4	5	3	4	3	5	4	5	3	4	3	5	4	5	3
	5	4	3	3	4	5	5	4	3	3	4	5	5	4	3	3	4	5

*X = with cognitive load, O = without cognitive load

Appendix F: Post-Test Questionnaire (for Phase 2)

Participant No. ________________ Date: ________________

Please indicate the extent to which you agree or disagree with the following statements.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. OnCourse CL is easy to use.	SA	A	N	D	SD
2. I always know where I am in OnCourse.	SA	A	N	D	SD
3. It is easy to get lost.	SA	A	N	D	SD
4. The amount of text and graphics on the Web site is appropriate.	SA	A	N	D	SD
5. The buttons and menus are easily understood.	SA	A	N	D	SD
6. The buttons and menus are easily located.	SA	A	N	D	SD
7. OnCourse CL is difficult to learn.	SA	A	N	D	SD
8. The online user guide is useful.	SA	A	N	D	SD

General Information

9. Age

□ <18 □ 18-25 □ 26-35 □ 36-45 □ 46-55 □ 56-65 □ >65

10. Gender

□ Male □ Female

11. Occupation

□ Undergraduate student

Please specify: □ 1st year □ 2nd year □ 3rd year □ 4th year

□ Graduate student

□ Faculty member

□ Other (please specify)____________________

Computer and Internet Experience

12. What kind of operating system do you use?

    ☐ Microsoft Windows ☐ Apple Macintosh OS ☐ Unix or Linux

13. What kind of Web browser do you use?

    ☐ Internet Explorer ☐ Mozilla Firefox ☐ Opera

    ☐ Netscape ☐ Other (please specify) ____________

14. How long have you been using computers (years)? _____________

15. How many hours each week do you use a computer? _____________

16. How long have you been using the Internet (years)? _____________

17. How many hours each week do you use the Internet? _____________

OnCourse (Old version) Experience

18. How long have you been using OnCourse (months)? _________________

19. How many days a week do you use OnCourse? _________________

20. How long do you spend each time on OnCourse (minutes)? _________________

21. Where do you usually access OnCourse from? (check all that apply)

    ☐ Home ☐ Computer Lab ☐ Work place ☐ Other (please specify) ______________

Appendix G: Post-Test Interview Session Form (for Phase 2)

Participant No. ________________ Date: ________________

1. What were the biggest difficulties you found on the previous tasks?

2. What did you like about OnCourse CL?

3. What did you dislike about OnCourse CL?

4. Do you have any comments or suggestions that you feel could help improve the interface of OnCourse CL?

Appendix H: Post-Test Questionnaire Results

OnCourse CL is easy to use.	N	%
Strongly Agree	1	3.23%
Agree	8	25.81%
Neutral	7	22.58%
Disagree	9	29.03%
Strongly Disagree	6	19.35%

I always know where I am in OnCourse.	N	%
Strongly Agree	3	9.68%
Agree	10	32.26%
Neutral	10	32.26%
Disagree	6	19.35%
Strongly Disagree	2	6.45%

It is easy to get lost.	N	%
Strongly Agree	6	19.35%
Agree	11	35.48%
Neutral	10	32.26%
Disagree	3	9.68%
Strongly Disagree	1	3.23%

The amount of text and graphics on the Web site is appropriate.	N	%
Strongly Agree	1	3.23%
Agree	5	16.13%
Neutral	10	32.26%
Disagree	15	48.39%
Strongly Disagree	0	0.00%

The buttons and menus are easily understood.	N	%
Strongly Agree	4	12.90%
Agree	7	22.58%
Neutral	6	19.35%
Disagree	9	29.03%
Strongly Disagree	5	16.13%

The buttons and menus are easily located.	N	%
Strongly Agree	2	6.45%
Agree	6	19.35%
Neutral	7	22.58%
Disagree	11	35.48%
Strongly Disagree	5	16.13%

OnCourse CL is difficult to learn.	N	%
Strongly Agree	2	6.45%
Agree	3	9.68%
Neutral	11	35.48%
Disagree	10	32.26%
Strongly Disagree	5	16.13%

The online user guide is useful.	N	%
Strongly Agree	0	0.00%
Agree	5	16.13%
Neutral	23	74.19%
Disagree	2	6.45%
Strongly Disagree	1	3.23%

Age	N	%
<18	0	0.00%
18-25	24	77.42%
26-35	7	22.58%
36-45	0	0.00%
46-55	0	0.00%
56-65	0	0.00%
>65	0	0.00%

Gender	N	%
Male	20	64.52%
Female	11	35.48%

Occupation	N	%
Undergraduate student: 1st year	6	19.35%
Undergraduate student: 2nd year	5	16.13%
Undergraduate student: 3rd year	2	6.45%
Undergraduate student: 4th year	10	32.26%
Graduate student	8	25.81%
Faculty member	0	0.00%
Other (please specify)	0	0.00%

What kind of operating system do you use?	N	%
Microsoft Windows	31	79.49%
Apple Macintosh	5	12.82%
Unix or Linux	3	7.69%

What kind of Web browser do you use?	N	%
Internet Explorer	28	68.29%
Mozilla Firefox	9	21.95%
Opera	0	0.00%
Netscape	4	9.76%
Other (please specify)	0	0.00%

Where do you usually access OnCourse from? (check all that apply)	N	%
Home	29	47.54%
Computer Lab	22	36.07%
Work place	7	11.48%
Other (please specify)	3	4.92%

	Mean	SD
How long have you been using computers (years)?	9.06	3.70
How many hours each week do you use a computer?	34.58	13.91
How long have you been using the Internet (years)?	7.52	2.36
How many hours each week do you use the Internet?	29.52	17.04

	Mean	SD
How long have you been using OnCourse (months)?	15.05	14.48
How many days a week do you use OnCourse?	3.49	1.95
How long do you spend each time on OnCourse (minutes)?	19.19	21.44

Appendix I: Post-Test Interview Results

What were the biggest difficulties you found on the previous tasks?	
Words or phrases	Occurrences
Move file	12
Create new folder	11
Understanding menu labeling	3
Find 001314 class (It is hided in the "more" drop-down menu)	1
Download file	1
Upload file	1
Navigating	1

What did you like about OnCourse CL?	
Words or phrases	Occurrences
Color looks nicer than the original OnCourse	3
Layout	2
There are more functions available.	1

What did you dislike about OnCourse CL?	
Words or phrases	Occurrences
The way some classes are hidden in the drop-down menu. One of them thought that the "More" drop-down menu will take him to other "options" not other "classes".	8
Feel disoriented when navigating inside folders. It is not obvious where the current location is.	6
Menu grouping and labeling	5
Too many menus on the left hand side.	4
Move button look unclickable. The pointer is still in an arrow shape (expected to see a hand shape)	4
Too much text	3
Layout	3
Color	3
Didn't know what the green arrow appeared after selecting Move Checked mean. *(This issue has already been fixed before this thesis research is completed.)*	2
Menus under "Actions" sometimes have an underline but sometimes do not	2

Comments or Suggestions that could help improve the interface of OnCourse CL	
Words or phrases	Occurrences
Classes should be listed by semester.	9
Mouse over should be a hand. (For "Move Checked" button.)	4
Expected the "Create Folder" function at the same position as the menu on the top (with Remove Checked, Move Checked, and Copy Checked)	2
On the left-hand-side menu, there should be icons in addition to the text labels. This might help users locate a specific menu faster and this also gives some idea about what each menu does.	2
Classes should be listed all at once, not hiding inside the drop-down menu.	2
The level of the files and folders inside Resources and Drop Box should be made more distinguishable.	1
The menu link on the left hand should bring users to the home page of that function every time. (After the users were pointed to the small arrow the top left corner of the portlet (window), they all said that they didn't notice it at all. This arrow is for resetting windows and it will bring users to the home page.)	1
There should be only one schedule for each student, not for each class.	1

VITA

Piyanaat Taksaphan

ptaksaph@iupui.edu
(317) 701-0661
765 Lockefield St. APT H
Indianapolis, IN 46202 USA

Education

Master of Science in Human-Computer Interaction, Expected Graduation: Aug 2006
School of Informatics, Indiana University Purdue University at Indianapolis (IUPUI)
Thesis: Cognitive Constraint in Using Learning Portals

Bachelor of Engineering in Computer Engineering, Graduated in July 2004
Chulalongkorn University, Bangkok, Thailand
Thesis: Experiments on Hand Geometry Verification System

Experiences

Part-time Web programmer, Aug 2005 – May 2006
Mathematics department, Indiana University Purdue University at Indianapolis (IUPUI)

- Developed web-based applications using PHP and MySQL
- Developed a data bank using MathML with MapleTA application

Internship, Apr 2003 – May 2003
Thai Airways International Ltd., Bangkok, Thailand

- Programmed flight simulator subsystem