



Internet Accessible Remote Experimentation with Integrated Learning Management System

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Abstract

Researchers and academics are developing Internet accessible remote laboratories, but only a few of them are in use for course delivery. One of the main drawbacks of developed systems is the lack of an efficient Learning Management System (LMS). Most of the available LMS are designed for lecture classes (online or hybrid) and are not suitable for Internet accessible remote experimentation. Considering the challenge, the authors have developed a custom designed LMS for an Internet accessible remote laboratory. This paper describes the design and development of an integrated facility with Internet accessible remote laboratory and an LMS. In terms of the remote experimentation part, it uses computer interfacing hardware and software from National Instruments (Input/Output cards and LabVIEW). The LMS part is mainly software tools that are implemented by using MySQL and .NET technologies.

1. Introduction

The presence of computer technology in education has increased dramatically, and predictions are that this trend will continue to accelerate. Many of the new technologies are interactive, and it is now easier to create environments in which students can learn by doing, receive feedback, and continuously refine their understanding and build new knowledge.³ The new technologies can also help people visualize difficult-to-understand concepts. With this scenario, academics and researchers are developing facilities for Internet accessible remote experimentations for a range of disciplines, and only few are in use for course delivery. The limitation of these facilities is the lack of a suitable Learning Management System (LMS). Considering the nature of the distance learning arrangements, these remote laboratories should have a comprehensive LMS. The requirements for this LMS are considerably different from the conventional ones used for traditional course delivery. The LMS should provide tools for course administration as well as provision for student facilities. In the course administration area, it should have provisions to activate/deactivate an experiment for Internet access, student access control and security, allocation of time slots for experiments, facility usage monitoring, and tracking of student progress. The student facility includes laboratory handouts and guidelines for facility usage. With this understanding, the authors have developed a remote laboratory facility that has an integrated LMS specifically designed for Internet accessible remote experimentation. The work reported through this paper is being conducted with the support of a National Science Foundation grant (DUE-0837138).

The developed facility has two components: one is the remote experimentation and the other is the LMS. The integrated facility is password controlled and has two levels of access, user level and administrator level. The user level of access is for students or users who are taking a remote laboratory course; the administrator access is for a faculty member or administrator who will be conducting a remote laboratory course. The development of LMS involves two areas, a database and web applications. The database part is implemented by using MySQL, and the web application part is done by using .Net technology. The facility is automated and operated by using a number of web applications. Provision has been made to collect a range of data

automatically. Web applications are developed to provide an initial analysis of the data, and at the same time all these data can be downloaded by an administrator to a local PC for further analysis. The remote laboratory part of the facility is implemented by using computer interfacing hardware and software from National Instruments (Input/Output cards and LabVIEW).

2. Internet Accessible Remote Experimentation

Traditional laboratory classes are scheduled for only a limited time period. Considering the mixed ability level of students, the allocated time is often not enough for all students to complete their tasks satisfactorily and also gain sufficient experience through the process.^{4,5} Sometimes students want or feel a need to perform additional experiments beyond their assigned tasks. It is usually difficult to accommodate any extra laboratory time due to the lack of available resources to keep the laboratories open. Additionally, laboratory facilities are often inaccessible to the students of other departments, even within the same institution, because of their geographical location. Ironically, too much laboratory equipment lies idle during most of its usable lifetime.^{6,7,8}

Only a remote experimentation facility can provide cost effective and unlimited access to experiments and maximize the utilization of available resources. Moreover, this will allow inter-laboratory collaboration among universities and research centers by providing researchers and students access to a wide collection of expensive experimental resources at geographically distant locations.

One of the major limitations of the existing Internet based distance-learning courses is their failure to deliver the laboratory-related courses.²⁷ While simulation and multimedia provide a good learning experience, for effective and complete learning, especially in STEM programs, a mixture of theoretical and practical sessions are needed. Currently, students from distance learning programs have to visit a campus to perform the laboratory sessions for a limited period of time, which is usually insufficient to allow them to complete their learning cycle.^{4, 10} Making the remote laboratory accessible through the Internet would address this problem.

Given a burning need for Internet accessible remote experimentation and the exponential advancement in the Internet and computer technologies and instrumentation the researchers/educators took the initiative to develop a number of remote experimentation facilities. Some recent initiatives have attempted to provide a couple of experiments on a dynamic systems and a basic electronics experiment over the Internet.^{11,12,13,14,15,16}

Despite all these developments, the popularity of remote experimentation has not yet gathered momentum. There are a number of issues impeding this progress; however, the main reason is the absence of an LMS that will support the delivery of a remote laboratory.

3. Remote Experimentation

The lead author has been working on remote laboratory development and implementation for more than ten years. During this period, he has attracted research and development grants from

the National Science Foundation and industries. Some of these developments are used to deliver laboratory courses within an electrical engineering technology program. This section will provide an outline of those developments.

To maximize the benefit of remote laboratories, the facility design philosophy includes a number of features: a) use of emerging technologies; b) individualized learning; c) knowledge-centered learning; d) embedded assessment strategies; and e) scaffolds. These features provide an engaging laboratory experience, work with students' pre-existing knowledge, and develop skills of self-monitoring and reflection, which contribute toward improving the quality of STEM education. The project experimentation part of the facility has two major components: a) a remote laboratory and b) pedagogical design.

3.1 Remote Laboratory

This implementation proceeds through a number of inter-linked tasks covering a range of disciplines, which include computer interfacing, web design, interactive graphical user interface, computer networking, network/web security, experiment module designs, assessment strategy, and project evaluation.

The developed facility can be presented by a generic architecture as shown in Figure 1. The facility consists of five main components:

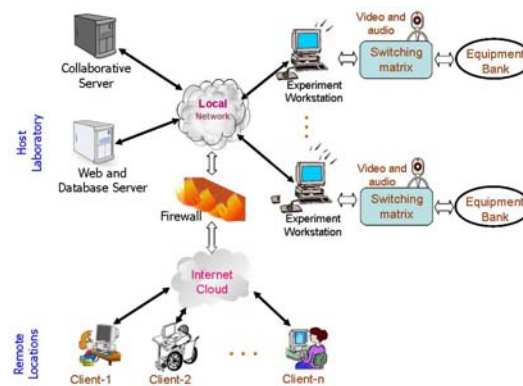


Figure 1: Block diagram of the developed remote laboratory facility.

1) web and database server, 2) experiment workstation server, 3) switching matrix, 4) equipment bank, and 5) video and audio. The web and database server, collaborative server, and experiment workstations are connected to a local network, which is then tied to the global Internet cloud via a firewall.

3.2 Pedagogical Design

The objectives of a traditional program expect that for a given laboratory course, a student should achieve his/her highest level at the end of the semester and a grade will be allocated on that basis. Considering the target courses that are parts of a traditional program and that each student progresses at his/her own learning pace, efforts were made for each student to achieve his/her highest level at the end of each topic within a given period of time. The pedagogical

tools within the developed environment, learning at their own pace as well as information on personal and class achievement levels, will encourage students to achieve their highest potential.¹⁷

Each week the faculty/administrator publishes an ‘Experiment module’ document through the web page. This document provides the identified objectives for that week along with a description of experiments (with detailed diagrams and instructions) that one can perform to achieve those objectives. In addition, students can use the provided experimental design or develop their own design and perform these as many times as they like. At the end of each week there is an assessment activity based on that week’s objectives.¹⁸

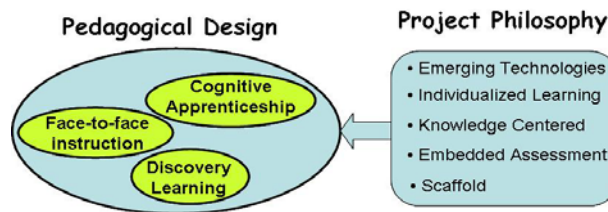


Figure 2: Pedagogical model in light of project philosophy.

There are various pedagogical design strategies one can utilize for a laboratory course design.¹⁹ To materialize the facility design philosophy (Section 4), the pedagogical design involves a blended learning approach by a synergic combination of three components: face-to-face instruction, cognitive apprenticeship, and discovery learning^{20,21} (Figure 2).

4. Developed Experiments

This section will provide a description of two experiments that developed for the remote laboratory facility. The first one is the control of a single-link flexible manipulator system and the second one is the control of a mobile robot (Roomba Create).

4.1 Flexible Manipulator System

The experimental system was acquired from Quanser Inc., a company who markets various educational products mainly in the control area. The flexible manipulator system is a single-link manipulator that can move only on a horizontal plane. The manipulator link is around 17 inches long, 0.82 inches in height, and 0.034 inches in thickness. At the hub, one end of the link is connected to a motor for its rotation. Four types of sensors are connected to the link to collect vibration and motion information: hub angle, hub velocity, strain information close at the hub, and end-point acceleration.^{22,23}

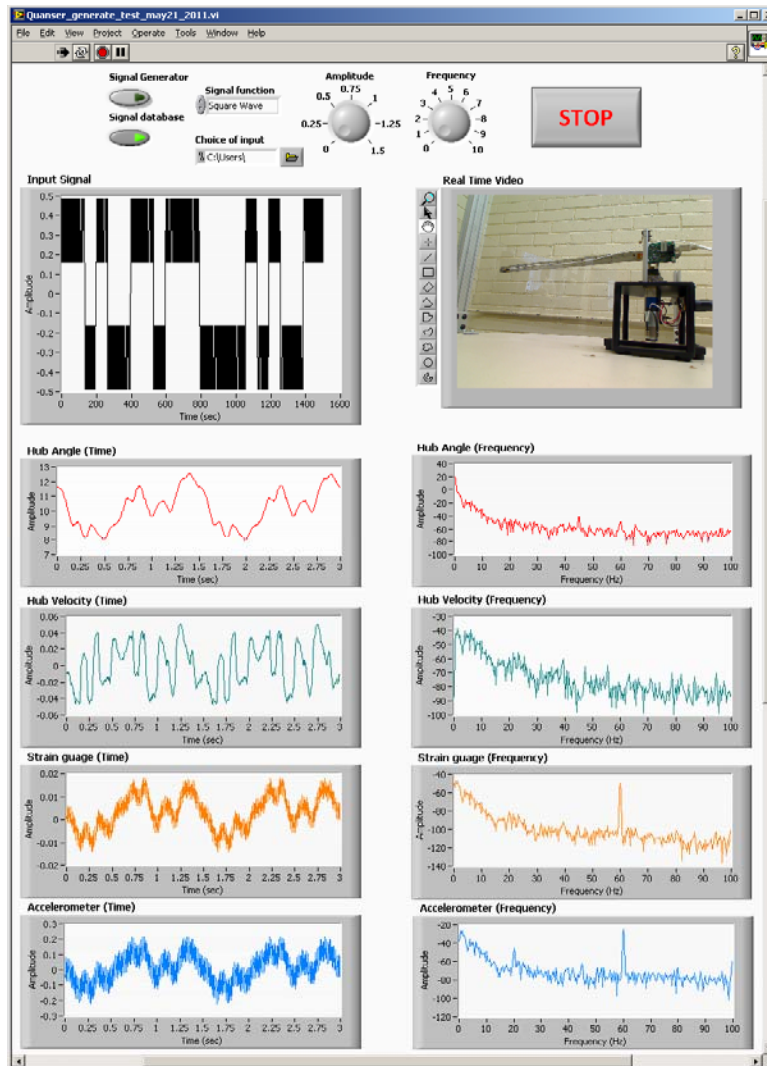


Figure 3: A GUI for studying the behavior of a flexible manipulator system.

Figure 3 shows an image of a graphical user interface that is used by a student to test the vibration properties of a flexible manipulator system over the Internet. The upper part of the GUI shows the control points where a student can start and stop the experimental system and choose an input signal to the system as well as control the properties of the input signal. Just below is a graph window showing the shape of the desired input signal as well as a video window showing the remotely located experimental system. The bottom part of the window shows four pairs of sensor signals that are collected from the experimental system (both in time and frequency domains). The right hand side ones are in the time domain and left hand side ones are in frequency domain. In addition, one can also download all the input and output signals on a local computer for further processing.

4.2 *Roomba Create*

The Roomba Create is a complete mobile robot development system that allows one to program new robot behaviors without thinking much about mechanical assembly and low-level code. The

system is developed by iRobot.²⁴ iRobot Create's Open Interface provides a set of commands, such as 'drive' commands, demo commands, song commands, and sensor commands. Using serial communication, these commands can be used to develop new behaviors, add third party electronics, and write Open Interface-based programs to control iRobot Create. One can also attach and control other hardware and electronic devices to iRobot Create, such as a robotic arm, light display, or a ranging sensor. For this project, a wireless camera is mounted on the Roomba Create so the camera view can be added to the GUI to provide a visual of the surroundings. An image of the Roomba Create with the camera mounted is shown in Figure 4. A suitable graphical user interface has also been developed so students can control the Roomba Create over the Internet. An image of the GUI with integrated control buttons, along with a video of its path as captured by the mounted camera, is shown in Figure 5. As it shows, there are a number of parameters that students can control as well as monitor some status indicators.



Figure 4: Picture of a Roomba Create mounted with a wireless camera.

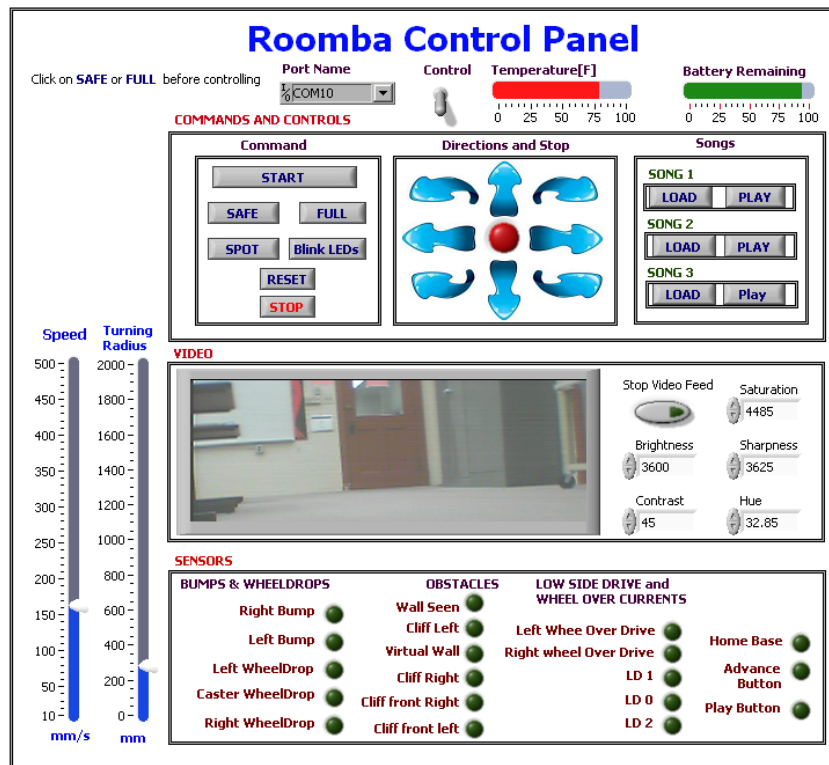


Figure 5: Image of the GUI for controlling Roomba Create over the Internet.

5. Learning Management Systems

A learning management system (LMS) is generally known as a software package that helps a course administrator deliver a course or training program. For commercially available LMS, commonly available features include delivery of course documents and presentations, collection of student works, reporting of grades, tracking of facility usage, etc.

In the US, most universities adopt LMS software and make it available to faculty members for course delivery. These are used for delivering online classes as well as for supporting hybrid course delivery. Some of the LMS software are open source and others are proprietary. The leading open source LMS include aTutor, Canvas by Instructure, Chamio, etc. When considering a proprietary LMS, one can mention Blackboard Learning System,²⁵ CERTPONT Systems Inc, Desire2Learn, etc. Within the proprietary ones, the Blackboard Learning System occupies more than half of the market share.

If we have all these LMS, why do we need another one? The main consideration for LMS software development was the requirements for teaching courses (online or hybrid). None of them catered to Internet accessible remote laboratories. With this scenario, an LMS has been developed to support remote laboratory delivery. Along with the standard features, the newly developed LMS allows management of the laboratory experiments, performance of experiments by the students, access control, experiment time allocation, a queue for experiment performance, weekly surveys, and tracking of facility usage.

6. Developed Learning Management System

The LMS has been developed to support an Internet accessible remote laboratory facility. The LMS is implemented using a web and database server. This allows the faculty/facilitator to a) integrate and configure experiments with the environment; b) create and manage user accounts; c) provide experiment guidelines, pedagogical and assessment tools, and survey questionnaires; d) activate/deactivate an experiment; e) monitor student activities in terms of use of an experiment; and f) monitor assessment outcomes. Most of these features are web-based and allow the faculty to perform those tasks over the web from any location. Along with other items, there is a database that contains all the pedagogical tools and resources, assessment items, user demographic data, password control data, user activity data (in terms of the use of the facility by individual users), student engagement data, and remote experiment utilization data. The database is dynamic, and some contents are updated automatically while the facility is in use. All these data are linked with an XML file, so they can be used by the environment. Each of the developed pedagogical tools and resources is considered an entity and is marked with unique identification within the database.

The technologies used for this facility are Hypertext Markup Language (HTML), Extensible Markup Language (XML), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL), Active Server Pages (ASP), .Net using C# as a programming language, JavaScript and Cascading Style Sheets (CSS).^{27,28} Based on remote instruction and using these technologies with the coordination of the database using SQL Server, this facility displays data/information to the user's (client's) web page. This facility is password protected, and the

protection is implemented through currently available technologies that allow web browsers and web servers to communicate over a secured connection.²⁶ The access control feature addresses authentication, confidentiality, and integrity.

A flowchart illustrating the functionalities of the developed LMS is shown in Figure 6. There are two levels of access for the facility, one is admin and other is the student. With the admin level of access, one can manage the accounts (both admin and student), post experiments, allocate students to a group, allot experimental time slots to each group, manage survey questions, monitor facility usage and survey results, and post announcements. The LMS implementation process involves database design and implementation along with front end design. An image of the login page is shown in Figure 7.

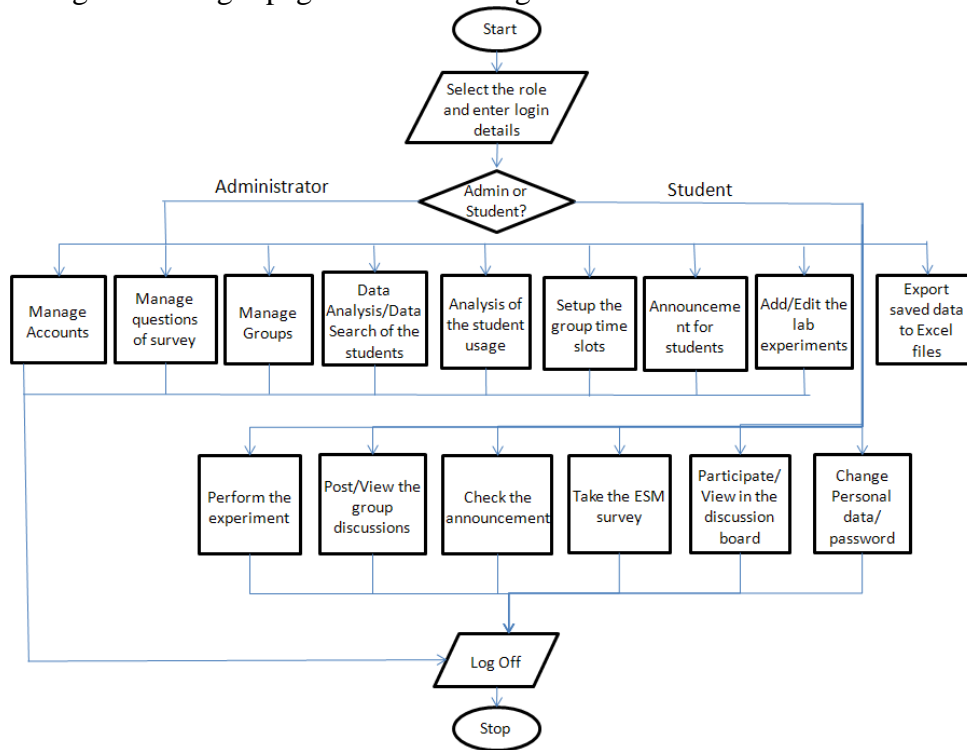


Figure 6: Flowchart of the developed learning management system.



Figure 7: Image of the login page.

With the admin level of access, one will have all the privileges for managing the facility. An image of the administrator home page is provided in Figure 8. It has seven options. These include Account Management, Student Group Management, Group Time Slot, Facility Usage Analysis, Student Tracking, Announcements, ESM Management, ESM Data Search, ESM Data Analysis, Weekly survey management, Laboratory experiments, and Data Downloads.

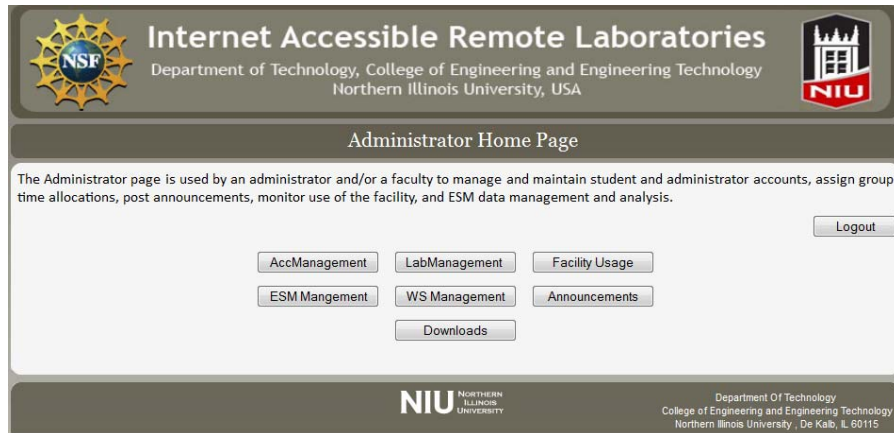


Figure 8: Shows the image of administrator home page.

6.1 Account management

This option is available via admin accounts. This has two options: one is administrator account management and the other is student account management. Within the student account management, there are four functionalities: student account details, new student account, and disable and enable an account. An image of the student account details is shown in Figure 9. The leftmost column of the table shows the 'Edit' button. A click on this button will open a new page where one can change the account details for a given account. Similar account management functionalities are available for admin accounts.

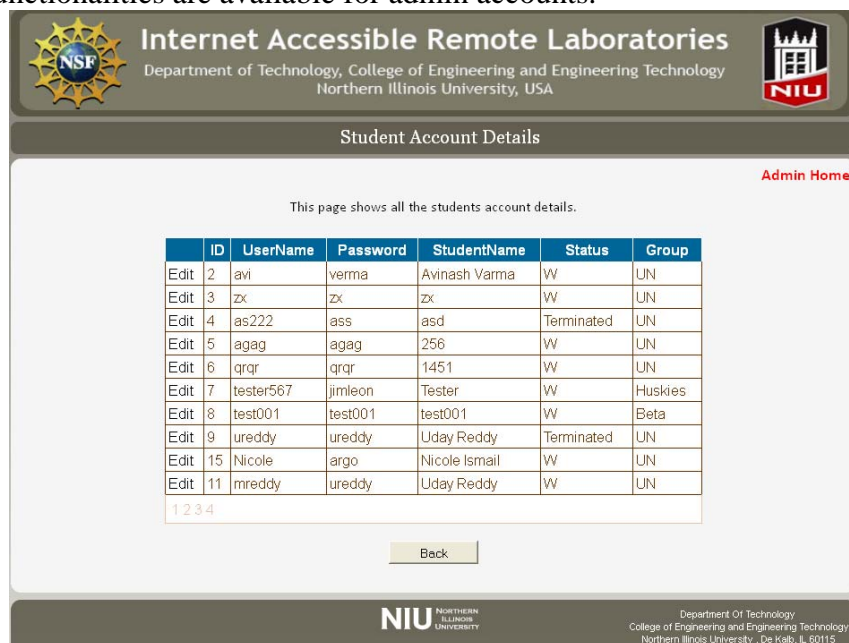


Figure 9: Shows an image of a student account details page.

6.2 Experiment page

This application allows an administrator to link a hardware experiment with the facility so the students can gain access to the experiment for its performance.

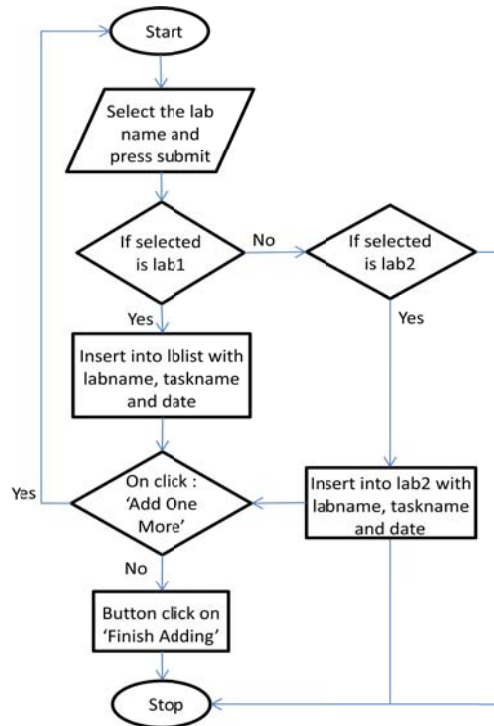


Figure 10: A flowchart for a laboratory experiment linking page.

Figure 10 shows a flowchart for this feature, while Figure 11 shows the front end of this application. As it is now, there are ten experiments available for posting for the students. With the drop down menu, one can choose which experiment(s) can be posted and then click on the submit button.

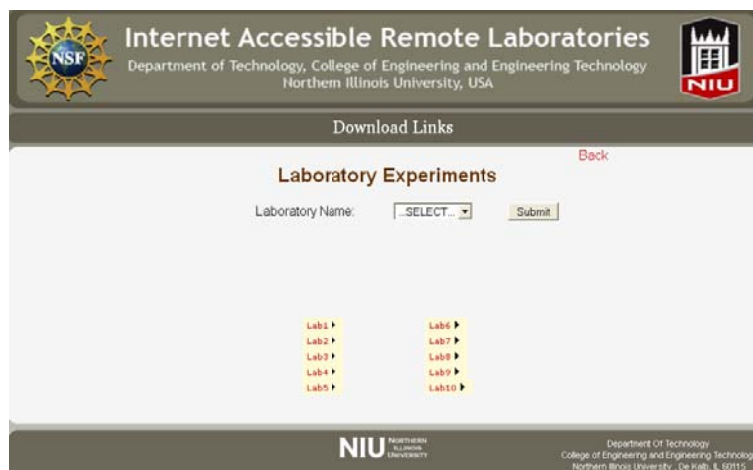


Figure 11: Front end image of the laboratory experiment linking page.

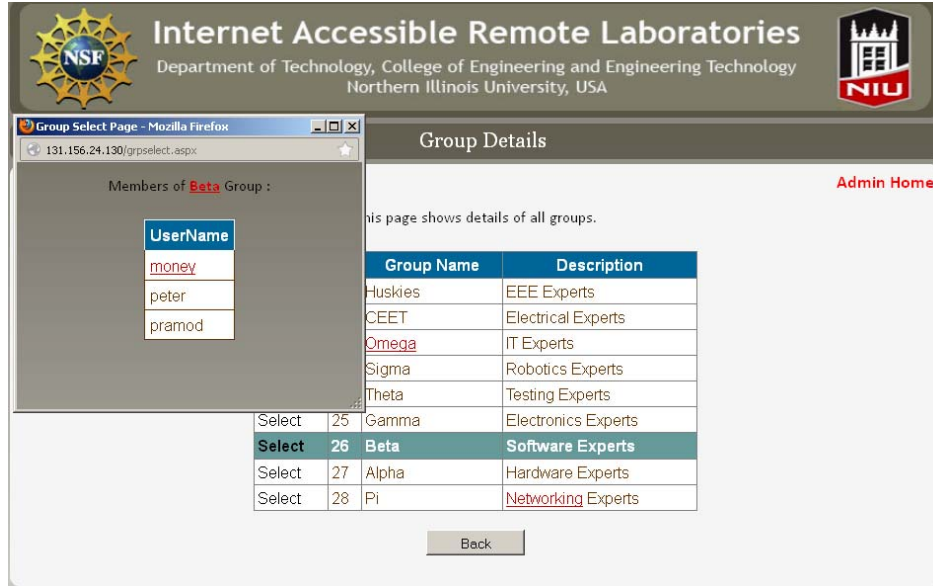


Figure 12: Image of a web page for laboratory group details.

6.3 Laboratory group management

Students are arranged in groups for efficient use of the facility. There is an arrangement to create groups, add or remove students to/from a group, and display group details. An image showing a list with group details is provided in Figure 12. To ensure the efficient use of the experiments, each group will have a scheduled time slot for gaining access to the experimental system. An arrangement has been made so that an administrator can allocate a time slot to each student group. A student group can access the experiments only within its allocated time slot.

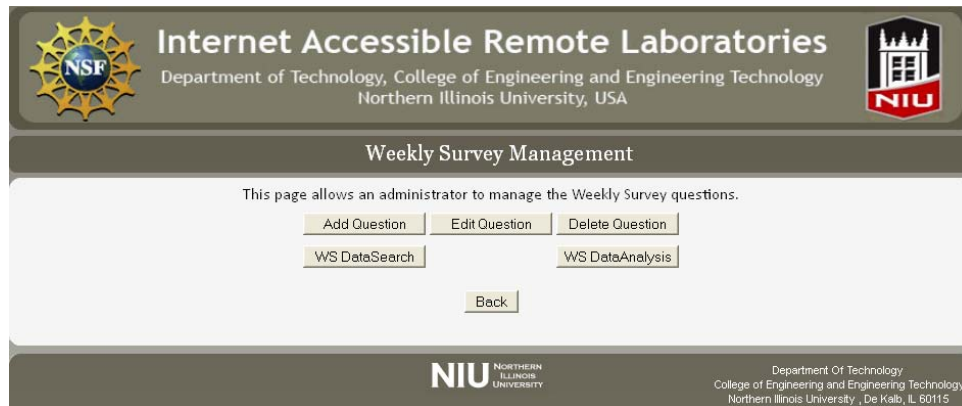


Figure 13: Shows the image of a weekly survey management page.

6.4 Weekly Survey management

At the end of each week, students will be prompted to take part in a weekly survey. This will allow the administrator to identify possible areas of improvement and act accordingly. An image

of the weekly survey management page is shown in Figure 13. With this application, an administrator can add a new question, remove or edit a question, and analyze the collected survey result.

The data analysis function allows one to perform two kinds of analysis. In one form, it provides a summary of the responses for all the survey questions for an individual student or all the students (Figure 14). The other form provides analysis on responses for an individual question for all of the students (Figure 15).

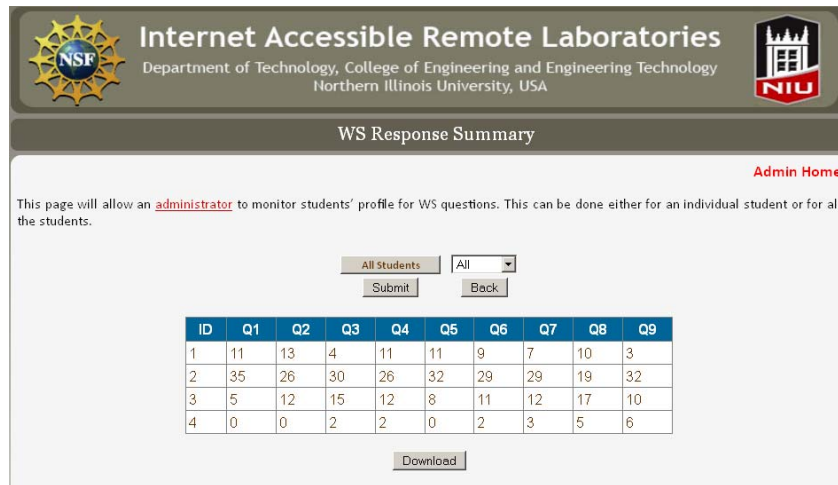


Figure 14: Shows the image of a weekly survey result analysis page.

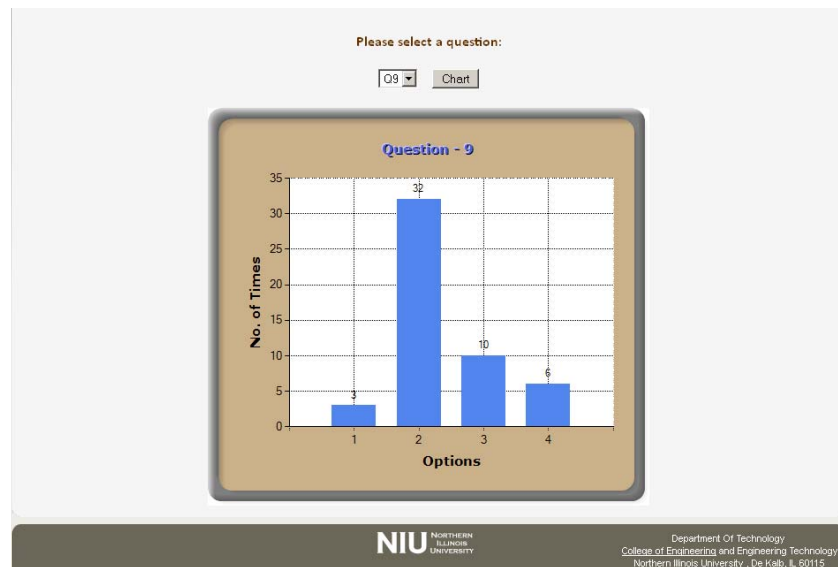


Figure 15: Shows a generated graph for responses to question-9 (weekly survey).

6.5 Experience Sampling Method

Student engagement will be measured as the mean of students' momentary ratings on Likert scales indicating enjoyment, concentration, and interest in a given activity. This measurement has been shown to have strong psychometric properties and is positively related to

achievement.²⁸ The Experience Sampling Method (ESM) will be used to gather data on the subjective experience of individuals while they are engaged in particular activities.²⁹ The ESM is a research methodology that asks participants to stop at certain times and make notes of their experience in real time. The point is for them to record temporal things like feelings while in the moment. There are different ways to signal participants when to respond to ESM questions. Traditionally, the ESM signaling was done by stopwatches; however, in this project provision has been made so that a pop up window will show up on the students' computer monitors. Students will be prompted (while using the environment) to respond to a number of scaled items in which they report their concentration, enjoyment, and interest in the activity they are doing at that moment as well as their perceptions of the challenges involved in the activity.



Figure 16: Shows the image of an ESM management page.

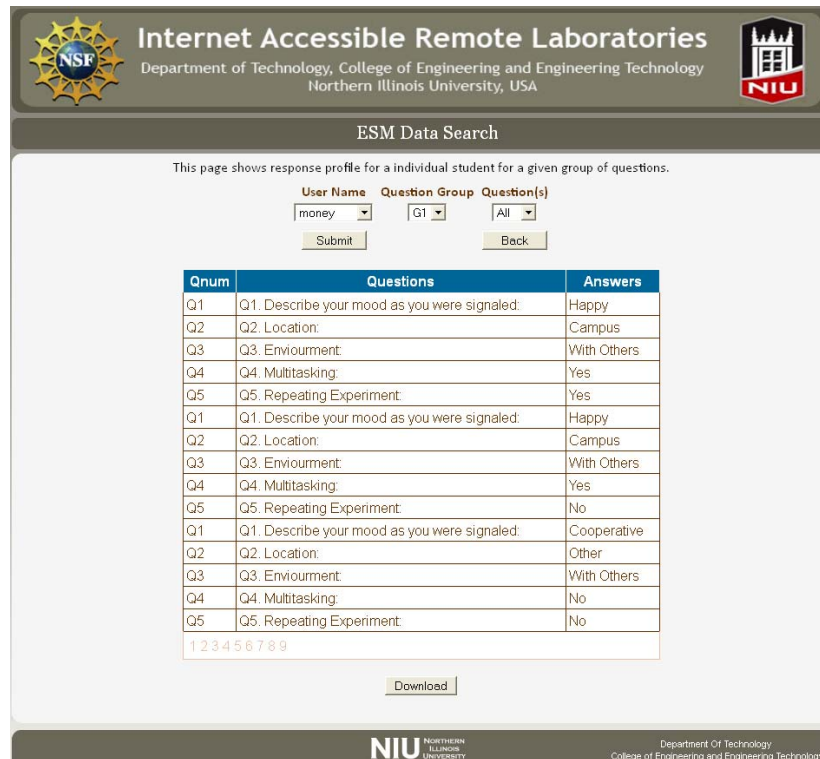


Figure 17: Shows an image of an ESM data search page.

There are three features within the ESM management page: ESM management, ESM Data Search, and ESM Data Analysis. The ESM Management option mainly allows an administrator to add a new ESM question and edit or delete an existing question. An image of the ESM management page with the options is shown in Figure 16.

ESM Data Search: This feature allows an administrator to monitor ESM survey responses for a specific student. With this arrangement, one needs to choose three items: student’s username, question group, and any specific question or all the questions within the group. An image of the ESM Data Search page for a given student is shown in Figure 17. This table shows all the entries of ESM survey responses the student took for G1.

ESM Data Analysis- This feature allows an administrator to get a summary of the ESM survey results for all the questions. This can be done for an individual student or for all the students within the database. An image of a page with ESM data analysis for a given student is shown in Figure 18. The table shows a summary of ESM survey results for a student with a username ‘money’. All 20 questions are considered for this table.

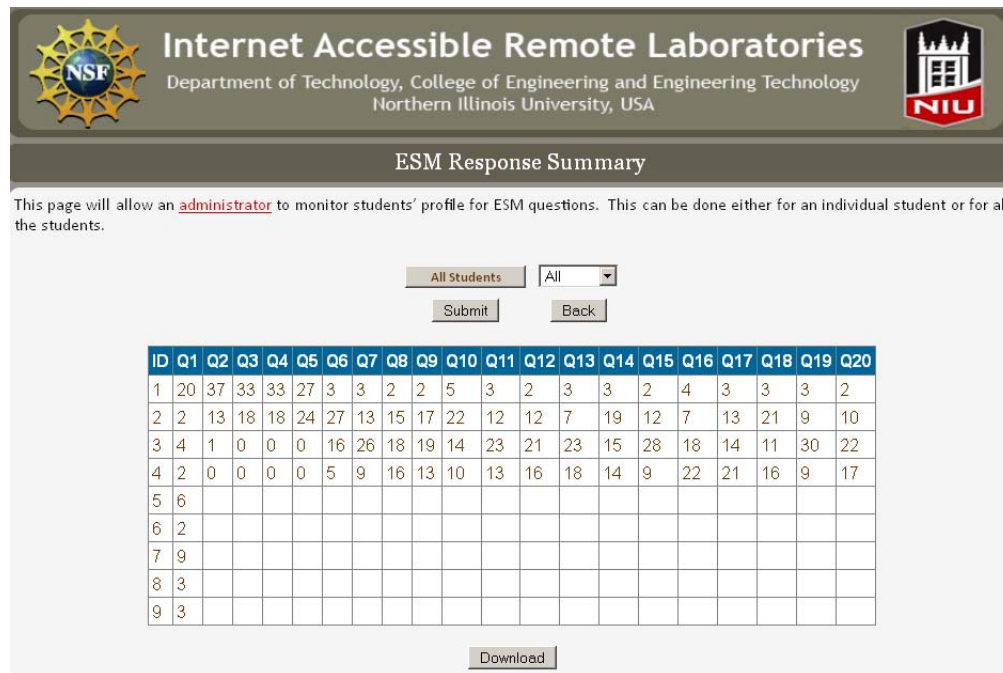


Figure 18: Shows the image of ESM data analysis page.

An administrator can also plot a graph of ESM survey results for a given question within a given group for all the students within the database. Figure 19 shows a graph for question 1 in which a summary results from all students are provided. There are nine possible responses for question 1, as it shows 11 students chose option 1, 2 students chose option 2, and so on.

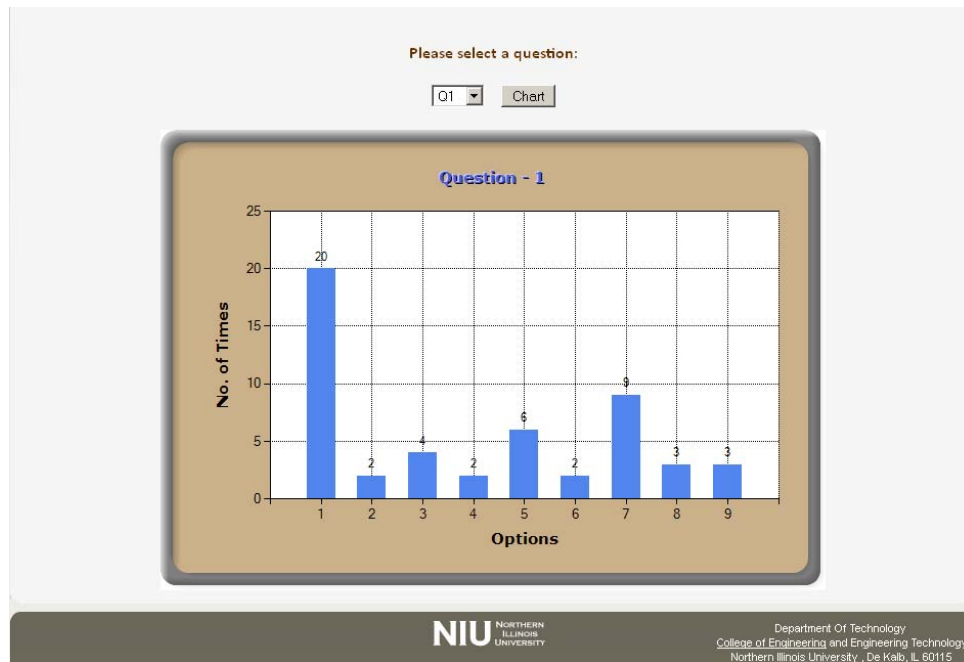


Figure 19: Shows a generated graph of question-1 for ESM.

6.6 Facility Usage Analysis

This feature allows an administrator to obtain various information on facility usage. An image of the page with facility usage analysis is shown in Figure 20. Within the page, one needs to choose a duration for the three analyses to be prepared. In this case the selection was made between October 16, 2012 and October 24, 2012.

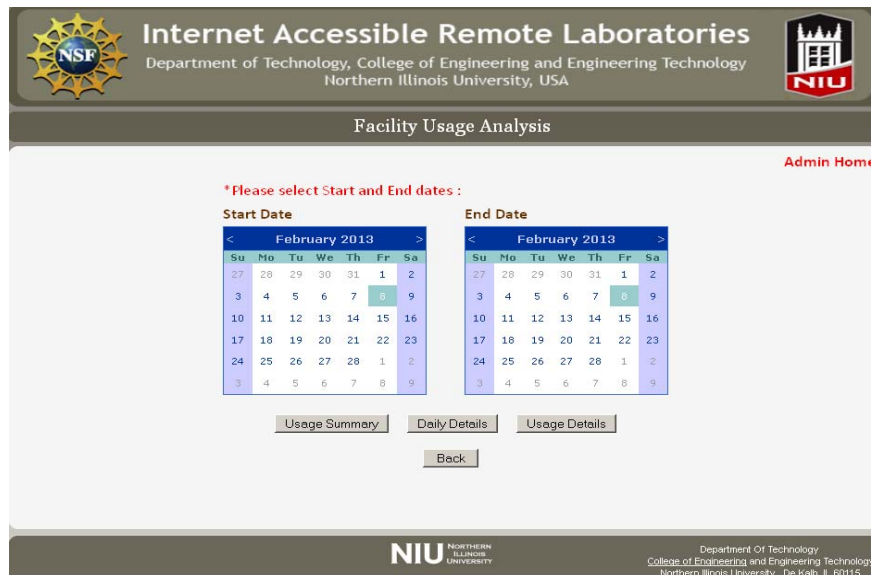


Figure 20: Shows an image of facility usage analysis page.

Usage Summary: Clicking on the ‘Usage Summary’ button will open a window, as shown in Figure 21. As it appears, there are 18 students logged in for this period; they logged in 73 times, visited 41 pages, and did not post anything on the discussion board. There are a total of 20 students in the database.

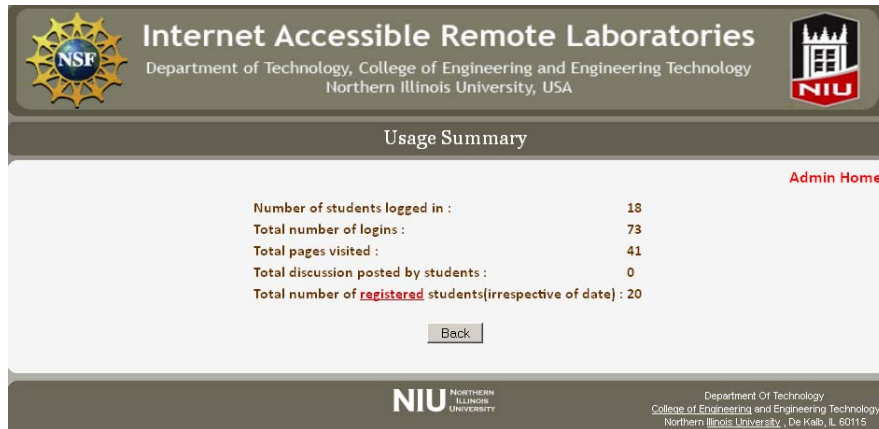


Figure 21: Shows an image of a facility usage analysis page.

Daily Summary: If one clicks on the ‘Daily Summary’ button with the same date setting, it will then open another page, as shown in Figure 22. This allows viewing of a number types of information for a six day period. The items included are number of students logged in, number of total logins, pages visited, number of discussions posted by the students, and number of registered students.

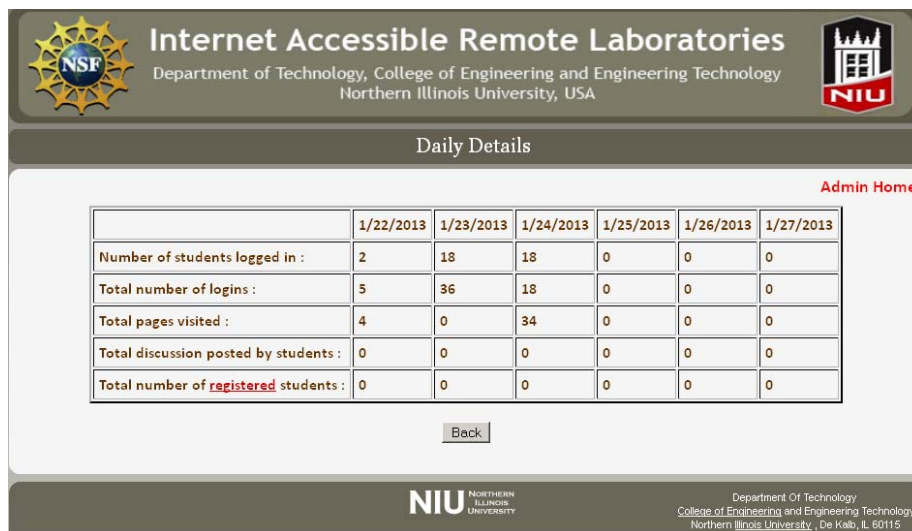


Figure 22: Shows an image of the daily details of facility usage.

Usage Details: With this feature an administrator can view the login and logout time for an individual student within a given date range. An image of the page is shown in Figure 23, where login and logout details of a student with the username ‘money’ are presented.

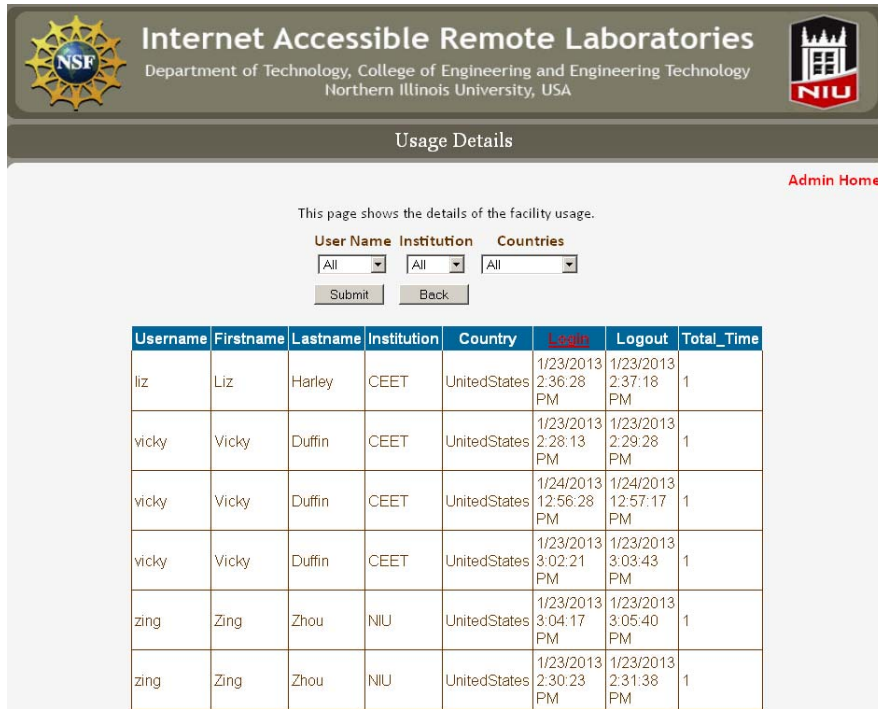


Figure 23: Shows an image of a usage details page.

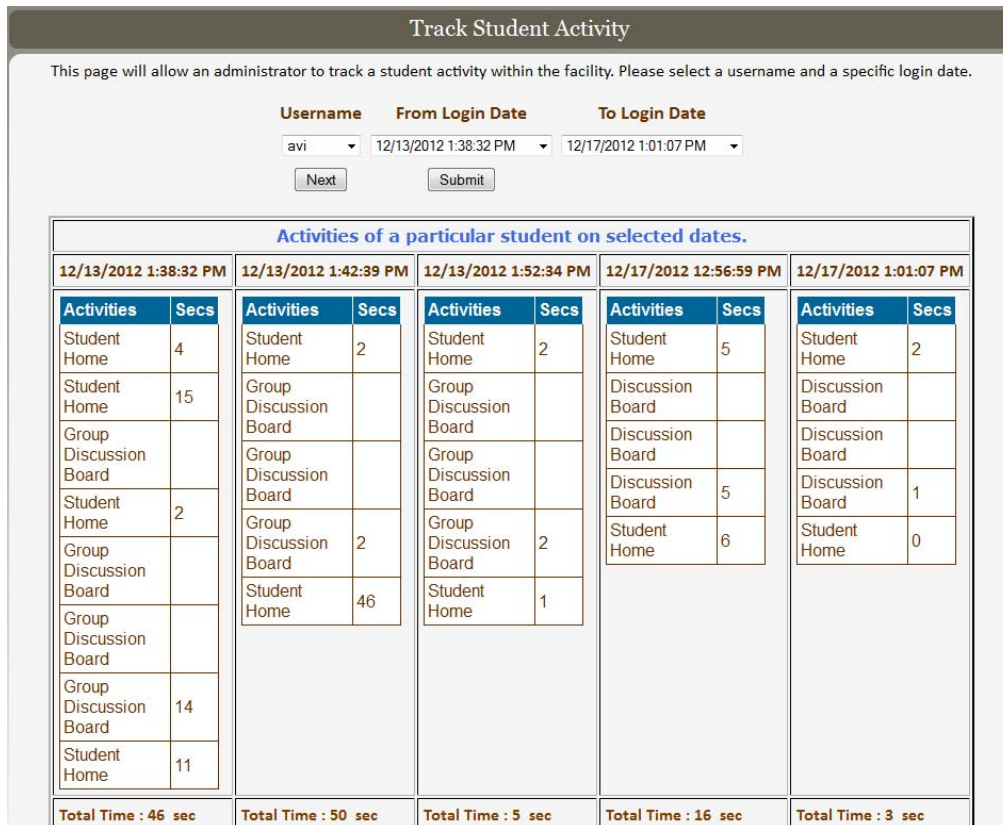


Figure 24: Shows an image of a student activity tracking page.

6.7 Student Tracking

Here an administrator can track a student's activity in much more detail. This feature provides a tabular presentation of the student's tracking data, one column for each login occurrence. Within each column, there is information for names of the pages visited along with the amount of time spent on that page. The bottom of each column shows the total amount of time spent for each login occurrence. Figure 24 shows an image of the Student Activity Tracking page.

6.8 Data Download

In addition to the analysis over the web (via various application pages), all the available data can be downloaded by an administrator and can be available for further analysis. An application page has also been developed to provide a central point for data downloading. An image of this page is shown in Figure 25.

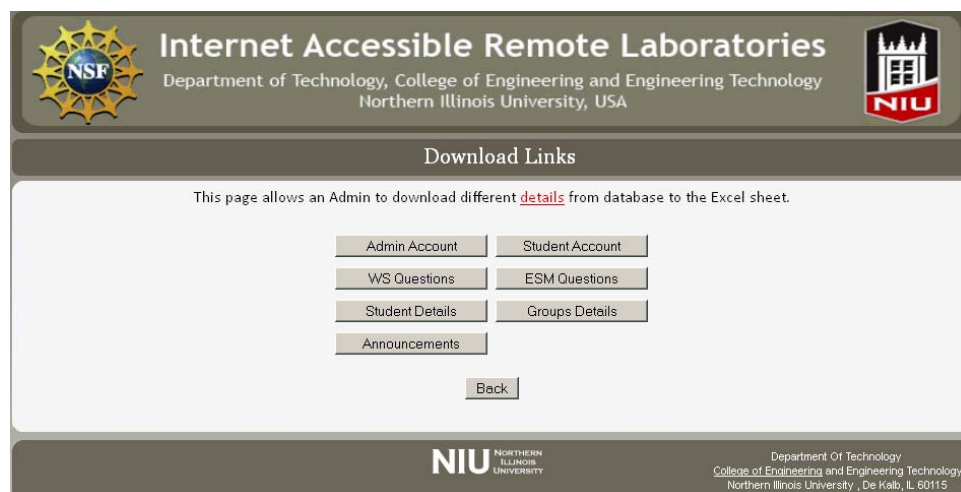


Figure 25: An image of the page showing the download links.

7. Conclusions

The paper provides an illustration of an Internet accessible remote laboratory facility with an integrated learning management system. The first part of the paper provides a description of the development process of remote laboratory, while the second part details the LMS that is being used to facilitate the remote laboratory. In addition, the LMS provides a means of monitoring and analyzing the usage of the facility through different web applications. Effort has been made to use cutting edge technologies to maximize the benefits of modern technologies throughout the development process. The lead author is planning to deploy the developed system by offering a laboratory course over the Internet. Once completed, the authors will be able to share the experience in the future.

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