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Inferring Student Learning Behaviour from Website Interactions: A Usage Analysis

JUDY SHEARD*, JASON CEDDIA and JOHN HURST
Monash University, Australia
E-mails: {Judy.sheard;Jason.ceddia;John.hurst}@csse.monash.edu.au

JUHANI TUOVINEN
Northern Territory University, Australia
E-mail: Juhani.Tuovinen@ntu.edu.au

Abstract

Web-based learning environments are now used extensively as integral components of course delivery in tertiary education. To provide an effective learning environment, it is important that educators understand how these environments are used by their students. In conventional teaching environments educators are able to obtain feedback on student learning experiences in face-to-face interactions with their students, enabling continual evaluation of their teaching programs. However, when students work in electronic environments, this informal monitoring is not possible; educators must look for other ways to attain this information. Capturing and recording student interactions with a website provides a rich source of information from data that is gathered unobtrusively. The aim of this study was firstly to explore what information can be gained from analysing student interactions with Web-based learning environments and secondly to determine the value of this process in providing information about student learning behaviours and learning outcomes. This study has provided critical information to educators about the learning behaviour of their students, informing future enhancements and developments to a courseware website and the teaching program it supports.

Keywords: Web-based learning environments, log file analysis, evaluation, post-secondary education

1. Introduction

Over the last decade, there have been dramatic changes in teaching practices in tertiary education. Arguably the most important impetus for these changes has been the emergence of new information and communication technologies, particularly the World Wide Web (Web). The rapid adoption of the Web by tertiary educators and its widespread use as a key component of course delivery is extensively reported (Hansen *et al.*, 1999; Kandies and Stern, 1999; Windschitl, 1998). Wang and Beasley (2002) assert that there has been an exponential growth in the use of the Web in education. Reports of studies of the extent of the use of the Web in universities support this claim (Peled and Rashty, 1999; Sheard *et al.*, 2001). The use of Web technology has meant many of the learner interactions with

* All correspondence should be addressed to: School of Computer Science and Software Engineering, Monash University, 900 Dandenong Rd, Caulfield East, 3145, Victoria, Australia.

content and other learners are now happening on-line, away from the direct observation and influence of the educators. It is therefore of critical importance for the design and delivery of course programs that educators know and understand how the students are using these Web environments and determine how useful they are for their learning.

The Web enables various ways to present and access information ranging from passive reproductions of paper-based documents to sophisticated interactive resources. Web-based resources can provide visual interest and different levels of interactivity, encouraging students to actively participate in the learning process (Lie and Cano, 2001; Sims, 2000). The Web allows flexibility of access to resources on or off campus and at any time, providing students with support for self-managed learning and facilities for group work (Arif, 2001; Comunale *et al.*, 2001–2002; Muirhead, 2001). The extent of use of the Web within teaching programs may vary from occasional non-essential use to the provision of an environment where all learner interactions happen online. Harmon and Jones (1999) identified five different levels of use of Web-based learning environments: Informational, Supplemental, Essential, Communal and Immersive; however, they stress that these are actually a continuum. Ingram (1999) provides a similar set of categories. Many educators incorporate a range of Web-based resources in their teaching programs and the organisation of these into an integrated environment provides an electronic learning space for their students. These environments are typically referred to as *Web-based learning environments.* Using a synthesis of descriptions from other researchers, Wang and Beasley (2002) define a Web-based learning environment as an environment in which units of multi-media forms of information are stored and can be "flexibly accessed electronically and globally through the multiple links in a hyperarchical interactive fashion by any appropriately connected users at any time" (p. 73). While Piguet and Peraya (2000), putting more emphasis on the learning define it as "a hypermedia based program or system that uses the attributes and resources of the WWW to facilitate learning" and further describe it as "a place where learners and teachers interact". An important feature of these environments is that they may be globally accessible or password protected.

The use of Web technology in tertiary education has resulted in fundamental changes in teaching and learning, bringing new focuses; this is considered by some to have provided a paradigm shift (Cornell, 1999; Federico, 1999; Hall, 1996). However, McDonald and Postle (1999) argue that there has been little change in the roles of educators or how teaching and learning are conceptualised. Furthermore, they claim that there is a lack of clear models for the teaching and learning that is occurring in the online teaching environment. Supporting these views, Lefoe (1998) proposes that a shift in pedagogy is needed by educators and claims that "many Web-based subjects have not utilised the full capability of this technology" (p. 454). Others also emphasise that adopting a Web technology into a teaching program should be accompanied by appropriate changes in pedagogy (Persichitte, 1999; Rogers, 2000).

Throughout the tertiary sector considerable effort is put into the design and development of Web-based learning environments and it is important that they are used effectively. Lambert and Williams (1999) stress that "teaching technologies should be regarded as enabling rather than deterministic and embraced with a view to improving student learning" (np). In support of this view, Bates (1997) declares that technologies should be matched to the

educational purpose. An advantage of the Web medium is that it can be used to develop an environment that can provide for the learning needs of a diverse group of students (Gillham *et al.*, 1999; Hansen *et al.*, 1999). However, to do this effectively it is essential to understand what the various needs of these students are and how they can be accommodated, enabling the provision of a sound pedagogical basis for the use of this technology (Lie and Cano, 2001). Furthermore, Arif (2001), by way of caution, proposes that it should not be assumed that educators and learners will use Web technology effectively. It is therefore important for educators to understand the impact of Web-based learning environments on learning experiences and learning behaviour so that they can make informed decisions about the provision of these environments for their students. This suggests a need for research into online learning which emphasises the pedagogical rather than the technological perspective (Mitchell *et al.*, 2001).

Determining students' learning experiences and behaviour in Web-based learning environments has provided particular challenges for educators. Electronic learning environments are often multifaceted and complex; students working in these environments are often remote from their educators. Information about student reactions to these environments can be gathered using conventional survey methods, however the continuous and subjective monitoring which occurs with face-to-face interactions is not possible and educators have had to seek new ways of gathering this information (Chen *et al.*, 2000). One source of information about students' use of Web-based learning environments is from records of interactions with these environments. These interactions can be recorded on log files or in a database and provide information on website usage in terms of frequency of access and time spent using the site. As the interactions are collected continuously, this process enables both formative and summative evaluation (Ingram, 1999). Federico (1999) states that "log files furnish unobtrusive windows for evaluating individuals' on-line learning without encroaching upon their cognitive and metacognitive processes employed in hypermedia environments" (p. 673). Another advantage of log file data is proposed by Ingram (1999) who suggests that measuring actual behaviour provides more reliable evidence than students' expressed opinions. However, he warns of the limitations of log file data, stating that they should be combined with other sources of information. The triangulation of log file data with surveys, observations or interviews is necessary to establish the difference between perception and reality (Ingram, 1999). As Peled and Rashty (1999) suggest, "if we mix these log files with student demographics and performance data and survey results, we will get a clear, powerful, and insightful picture of how students learn online" (p. 428).

Various studies have analysed data of student interactions with course websites. The most common analysis is the calculation of frequency and times of access to determine usage patterns (Ingram, 1999; Peled and Rashty, 1999). Several studies have found a relationship between the perceived usefulness and usability of website resources and usage of these resources (Comunale *et al.*, 2001–2002; Piguet and Peraya, 2000). An investigation by Selim (2003) found that usefulness was a key determinant of website usage, although ease of use was only indirectly related to usage. More difficult to establish is the relationship between learning outcomes and website usage; however, Comunale (2001–2002) found strong evidence to suggest that higher course grades are related to more frequent website use.

The study reported in this paper investigated the type and value of information that can be gathered from analysing student usage of a Web-based learning environment. Taking a different view from most studies which have explored the impact of various factors on website usage, the question of interest in this study was, "What can educators' infer from student interactions with a Web-based learning environment in regard to learner behaviour, usefulness of resources and learning outcomes". As a context for this study, data from a website developed to assist students in their industrial experience project work was used. Student interactions with the website were automatically collected and recorded in a database. The analysis of this data provided information on usage of the site; in particular, frequency of access to the site, types of resources accessed, and time spent in the site. This gave a view of learning behaviour and indications of the usefulness of resources. The students' explicit ratings of the usefulness and effectiveness of the website and the resources it provided were collected via an on-line survey and a paper survey enabling verification of inferences made from the analysis of the interactions data. Finally, the demographic data enabled comparisons to be made based on gender and course performance providing further insights into the work patterns of different groups and enabling the relationship of site usage and learning outcomes to be determined.

The questions which guided this investigation were:

- How often and when did students access the site?
- What resources did students use?
- What time did students spend at the site?
- What were the patterns of use over the year?

Determining student use of and reactions to a Web-based learning environment can inform educators about the appropriate pedagogical models to use when incorporating these environments into their teaching programs (Peled and Rashty, 1999; Yates, 2000). Furthermore, this information can be used in formative evaluation to assist educators establish a pedagogical basis for decisions when designing or modifying an environment or teaching approach. The ultimate goal is to create useful and usable learning environments for our students (Ingram, 1999).

2. Context of the Study: The WIER Web Site

Students in their final year of the Bachelor of Computing degree at Monash University undertake an industrial experience (IE) project in which they design, develop, and deliver a small computer system for a client. The project runs for two consecutive semesters and comprises one quarter of the normal workload for the final year of this degree program. Students are organised into groups of five for their IE project work. This provides them with real-life experience in project co-ordination and management. A full description of the IE project course can be found elsewhere (Hagan *et al.*, 1999).

The WIER website was developed by staff in the Faculty of Information Technology to provide students with an integrated learning environment to use during their IE project work. It is required that the students use the site for their IE work and the intended level of

use fits with the third category of "provider of required instructional information" (p. 154) provided by Ingram (1999) and the third and fourth categories of "essential" and "communal" provided by Harmon and Jones (1999). The site provides various resources including general project information, a facility to enable event scheduling, facilities for project management including a task/time tracker, time graph generator, file manager and risk management, and various forms of communication facilities via news groups and discussion forums. The site also provides access to a repository of resources including standards documents, document templates and samples of past projects. More details about the WIER site are provided elsewhere (Ceddia *et al.*, 2001).

3. Research Study

This study aimed to determine what educators can infer from student interactions with a website. The data used in this study were collected during an evaluation of the student use of the WIER website. This was performed by teaching and research staff in the School of Computer Science and Software Engineering at Monash University during 2001.

3.1. Participants

In 2001 there were 172 students enrolled in the IE project course. The students were organised into 35 project groups. The WIER website interactions data were collected for all students. Seventy-seven students participated in the on-line survey and 155 participated in the paper survey. There were 115 (67%) male and 57 (33%) female students in the group. For the purpose of comparison the top 25% of the students according to their final IE result were classified as the high achieving group and the bottom 25% were classified as the low achieving group.

3.2. Data collection apparatus

Data were collected using the following apparatus:

On-line Logging: Details of all interactions[1] with the WIER site were stored in a Microsoft Access database. The information recorded for each interaction identified the user code, page accessed, and time of access.

On-line Survey: An internal facility included in WIER enabled the dynamic creation of surveys with the specification of a date activation range and intended participants. Using this, a survey was set up to gather students' opinions of the usefulness of the WIER site.

[1] In this report an *interaction* is defined as a selection of a website URL.

Paper Survey: A paper survey was used to determine students' opinions of the usefulness of the WIER site at the end of their project work. The survey contained both single response and open-ended response questions.

3.3. Method

All online interactions with the WIER website were collected over 27 weeks, from early in Semester 1 (week 5) until the end of Semester 2 (week 31). This data collection formed a naturalistic enquiry, a paradigm describing a situation where data is collected in a natural setting unnoticed by the learner (Sarantakos, 1998). The data collection period covered almost the entire length of time the students had access to the site.

The on-line survey was conducted over a four week period (weeks 9–12) at the end of the first semester. This was used as a formative evaluation. The survey was accessed from the WIER site when the students logged on and was not shown once it had been responded to or was out of date. The students were notified about the survey at their weekly seminars. Participation was voluntary and despite continual reminders and encouragement to participate, the response rate for the on-line survey was only 44%.

The paper survey was conducted at the end of the year when the students had completed all of the requirements for their IE project work. This was used as a summative evaluation. The survey was administered to the students at the session where they presented their final IE project work. The original intention was to collect this data on-line; however, given the low response rate for the first survey it was felt that a paper survey might elicit a better response rate, and this was indeed the case. The response rate for this survey was 89%.

3.4. Data analysis

To enable the data to be interpreted in a meaningful way the pages on the WIER website were categorised according to a particular resource or facility provided on the site. For example, pages used to record or view a project time were categorised under Time Tracker and the page that held the timetable of events was categorised under Calendar of Events. These page categories, which from now on will be referred to as resources, are listed in Table 1. This table also shows various classifications for the resources as follows:

- *Static* is used for resources which are produced once and rarely or never updated; *dynamic* for resources which are modified or developed over the teaching period.
- *Passive* is used for resources that are reproductions of paper resources; *interactive* for resources that incorporate elements that require or allow interaction with the user.
- *Group* is used for resources which facilitate group communication or activities; *individual* for resources used individually.

The data were analysed using the statistical package SPSS. Data were prepared for analysis using a computer program written in C++. Using this software, data files containing details of access times were set up. For the purpose of the analysis three types of access times were defined as follows:

Table 1. Description of Page Categories on the WIER site

Resource (Page Category)	Description	Group/ individual	Static/ dynamic	Passive/ interactive
Home Page	Entry page for site. News items.	Ind	D	P
Time Tracker	Facility to record project tasks and times spent. Generates fortnightly task and time reports.	Grp	D	I
File Manager	Facility for groups to store and retrieve files in a Web-accessible location. Configuration management facilities.	Grp	D	I
Document Templates	Document templates and examples of documents from past projects.	Ind	S	I
Risks Lists	Facility to assist project risk management.	Grp	D	I
General Information	Static documents, guidelines, assessment guides.	Ind	S	P
Group Forum	Group based discussion forum.	Grp	D	I
Group News System	Facility to post news items to group members.	Grp	D	I
Calendar of Events	Allows viewing and scheduling of events.	Ind	D	I
Past Projects	Repository of past projects. Facilities to search projects from previous years with the possibility of reusing code.	Ind	D	I
Discussion Groups	Discussion forum for all students.	Ind	D	I
Resource Search	Searchable database of on-line resources and printed material. Students may submit details of resources to this database.	Ind	D	I
Administration	Not accessible by students.	–	–	–
Surveys	On-line surveys to provide feedback about the site.	Ind	D	I

- A *session* was defined as a sequence of interactions of a user from a login to the last interaction with the site before logging out or moving to another site and not returning. (This is defined as a *server session* in the Web Characterization Activity Statement, http://www.w3.org/WCA/Activity.html)
- A *task* was defined as a sequence of interactions of a user within one resource. The time of a task was calculated by measuring the time interval from the first interaction within a resource until the last interaction within that resource or the first interaction with another resource within the same session.
- An *activity* was defined as an interaction within the site and categorised to indicate whether the activity indicated browsing or reading or more interactive use. The time of an activity was defined as the time interval from the previous activity within the same resource. If the previous activity occurred on another resource, the activity was defined as a changeover activity, describing the decision of the student to move to another resource. In this case, the time was recorded with the time of the previous resource accessed.

4. Results and Discussion

4.1. How often and when did students access the site?

The frequency of access to the WIER website and the times of access gave an overall view of the usage of the site and indications of the students' learning behaviour in terms of their work patterns over the year.

There were 9442 student sessions recorded on the WIER site during the 27 week data collection period; a mean of 51.0 sessions per student giving almost two sessions per week per student. However, there were huge variations in the number of accesses as indicated by a standard deviation of 41.1. The lowest number of sessions was one and the highest was 269. One student had 629 accesses, however over 400 of these were repeated login attempts during a period of several hours, and these have been excluded from the analysis. Differences were found in access to the site based on gender. The mean number of sessions for female students ($M = 64.2$, $SD = 55.7$) was significantly greater than that of the male students ($M = 44.0$, $SD = 29.5$, $t(169) = 3.11$, $p < 0.05$). However, no differences were found based on course performance. Although the high achieving students recorded more frequent use of the site ($M = 59.6$, $SD = 57.2$) than the low achieving group ($M = 44.1$, $SD = 33.1$), this difference was not significant and from this we cannot deduce that frequent access to the site was beneficial for their IE project work.

The site was accessed by the students throughout the entire 27 week data collection period. The frequency of sessions per week during this time is graphed in Figure 1. The

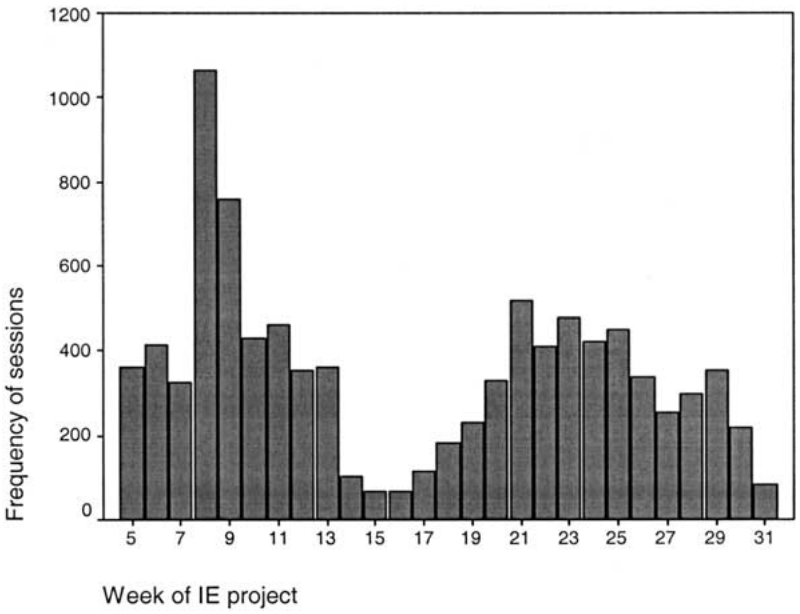

Figure 1. Frequency of access to WIER per week.

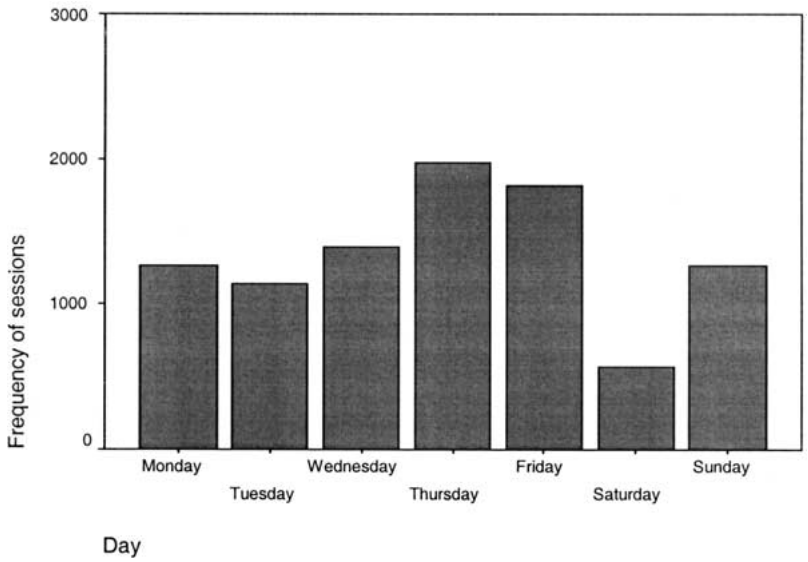

Figure 2. Frequency of access to WIER per day of the week.

variations in pattern of access can be explained by various events during the course of the IE project. The lowest numbers of sessions occurred in weeks 14, 15, and 16 which was during the examination period when the students typically do not spend much time on their IE project work. The three week period following this was a mid-year break between semesters. During this time students take the opportunity to work on their IE projects or take a holiday. It seems from the low numbers of sessions for these weeks that a holiday is the preferred option for many. The highest numbers of sessions were recorded in weeks 8 and 9, just before the submission date of the first major assessment component, the functional specifications. Preparation for this assessment involved students in a range of tasks on the WIER site including accessing Document Templates, File Manager and Past Projects. The students were also most active in the Discussion Groups and the group forums at this time in the year.

The distribution of sessions over the course of a week is graphed in Figure 2. This shows that the students used the site every day of the week including the weekend. The pattern of sessions throughout the day as graphed in Figure 3 shows that the site was accessed continually throughout the day, even in the early hours of the morning. It is interesting to note that the highest frequency of sessions each day, on average, occurred just before midnight.

4.2. What resources did students use?

The frequency and patterns of access to resources on the WIER website gave further insights into the students' learning behaviour and also gave indications of resources that the students found useful and were beneficial to their work.

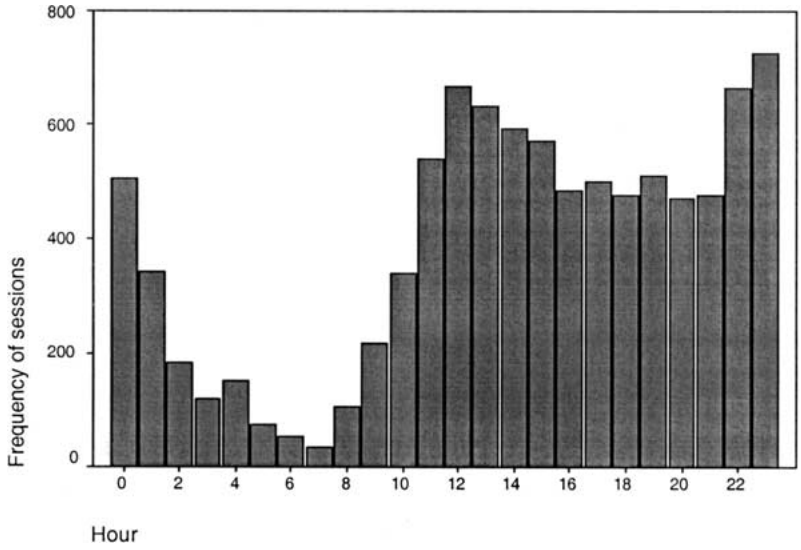

Figure 3. Frequency of access to WIER per hour of the day.

The frequency of access to each type of resource varied over the course of the year, as shown by the graphs of access patterns for the Time Tracker, File Manager and Document Templates and provide a view of student work patterns (refer Figures 5, 6 and 7). The variation in patterns of access over the year can be explained by various factors. In some cases these relate to IE project events. For example, the high accesses to most resources in weeks 8 and 9 indicate that many students explored WIER at this time. These followed a seminar presentation which demonstrated the site and preceded the first major submission for their IE project work. In other cases the pattern of use can be explained by the type of resource. For example, some resources such as the Document Templates are only useful at certain stages of the IE project work when students are setting up templates for project documentation. Other resources are useful throughout the year, for example, the File Manager, or need to be accessed regularly, for example, the Time Tracker. An interesting pattern was shown with the pattern of access to the Time Tracker. The students were supposed to enter their project times each week and submit a report each fortnight, however the high access on alternate weeks indicates that many chose to enter their times fortnightly, just before the report was due.

There were huge variations in the frequency of access to resources on the WIER site as shown in Figure 4. All students entered the WIER site via the Home Page. The most frequently accessed resource on the site, after the Home Page, was the Time Tracker, which was accessed at 61% of the sessions. All students were required to use the Time Tracker each week to record their project times, which most likely explains its comparatively high use. The next most accessed resource was the File Manager, which was accessed at 26% of the sessions. This resource gave each IE group access to a repository for their IE project files. It was not required that they use this resource to manage their files; however, the

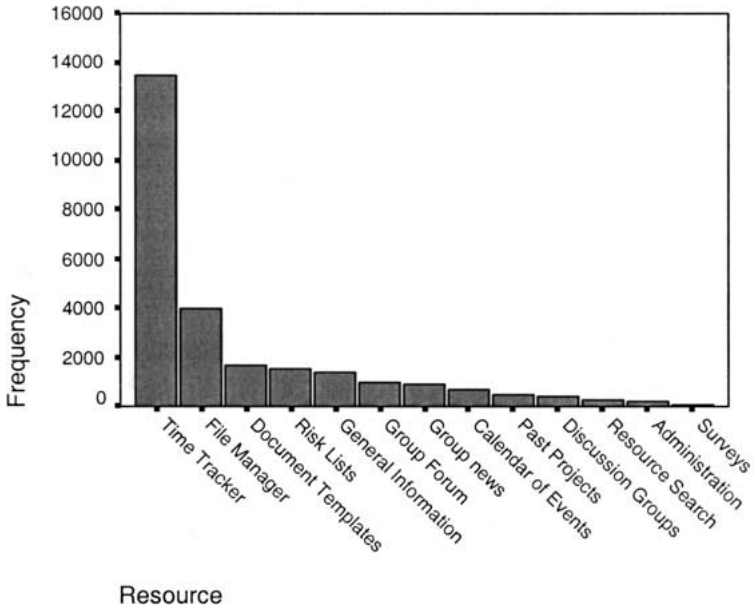

Figure 4. Frequency of access to resources.

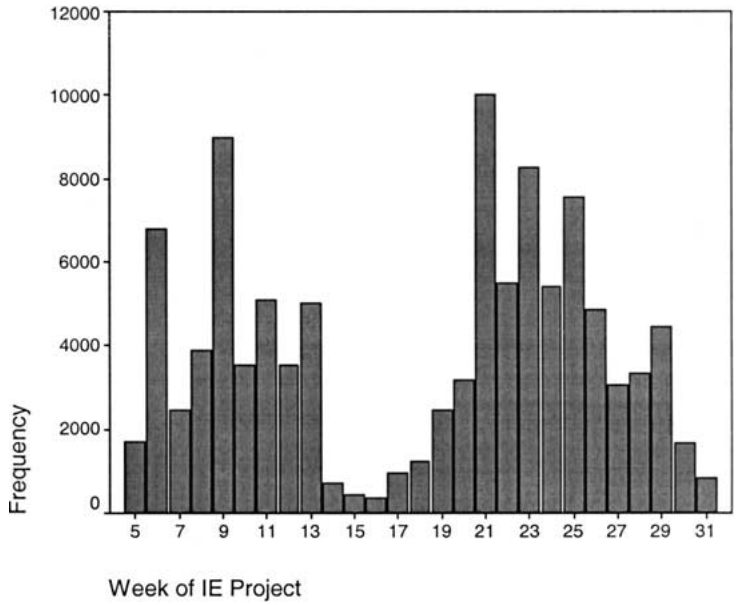

Figure 5. Frequency of access to Time Tracker.

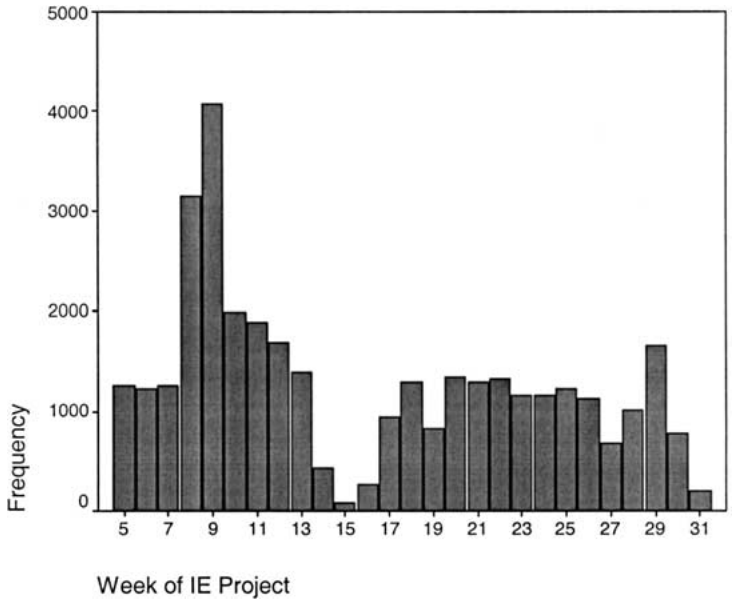

Figure 6. Frequency of access to File Manager.

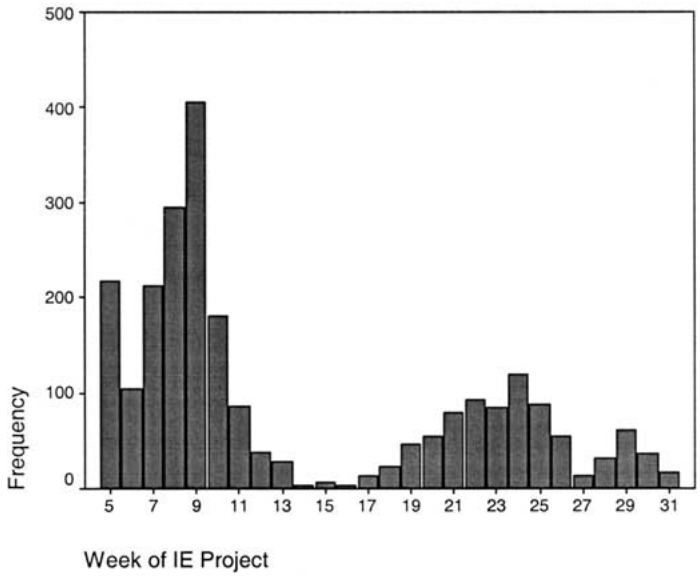

Figure 7. Frequency of access to Document Templates.

high usage of this resource and the continual use over the year (refer Figure 6) indicates that many groups found it useful. All other resources were accessed at less than 10% of the sessions. Differences in access of resources were shown between different groups of students. Females accessed each resource proportionally more than the males except for the Discussion Groups. A cross tabulation showed there was a significant difference between the frequency of the male and female accesses ($\chi^2(12) = 181.1$, $p < 0.05$). The greatest difference was shown for the Time Tracker where the mean number of accesses for female students ($M = 850.7$, $SD = 486.3$) was significantly greater than the male students ($M = 531.9$, $SD = 260.3$, $t(170) = 5.60$, $p < 0.05$).

In interpreting frequency of access to determine usefulness, the type of resource must be considered. Low usage does not necessarily indicate that these resources were not useful to the students. In some cases the low usage can be explained by the limited application of the resource (Past Projects) or the limited amount of information the resource provided (Resource Search). In other cases, student usage of a resource depended on their role within their project group (Document Templates). However, for the communication resources of Discussion Groups and Group Forum, the low usage could be interpreted as a preference not to use these resources and indicates that the students did not find them useful.

Another aspect considered was the value of the WIER site for the students' project work. To determine any relationship between a successful project outcome and the students' use of the WIER site, Pearson product-moment correlation coefficients[2] were calculated for the students' results with the number of accesses to the site, the number of interactions with the site and the number of interactions with the Time Tracker. There were significant positive relationships between the students' results and their interactions with WIER ($r = 0.22$, $p < 0.01$) and between the students' results and their interactions with the Time Tracker ($r = 0.29$, $p < 0.01$). Furthermore the high achieving students recorded significantly more interactions with the site ($M = 1391.3$, $SD = 1134.7$) than the low achieving group ($M = 867.3$, $SD = 425.4$, $t(86) = 2.82$) and the high achieving students recorded significantly more interactions with the Time Tracker ($M = 818.7$, $SD = 604.3$) than the low achieving group ($M = 486.6$, $SD = 207.8$, $t(86) = 3.38$). No relationship was shown between login and results. This indicates that it is actual engagement with the site rather than access, which is important to successful project outcomes.

In summary, website usage patterns can give a view of student learning behaviour and can be used to make some inferences as to the usefulness of resources and learning outcomes. The resource usage patterns of the WIER website showed that the students had little interest in engaging with the site beyond what was necessary for their project work. Most of their use of the site was focused on the functional project resources rather than resources provided as additional support. This usage behaviour has also been found in other studies of student usage of courseware websites (Cann, 1999; Heines, 1998). Furthermore, the students' use of the WIER site appeared to be targeted towards their own needs. They showed a reluctance to contribute to the site or engage with other learners or

[2] A correlation coefficient gives a measure of the degree of a relationship between two variables.

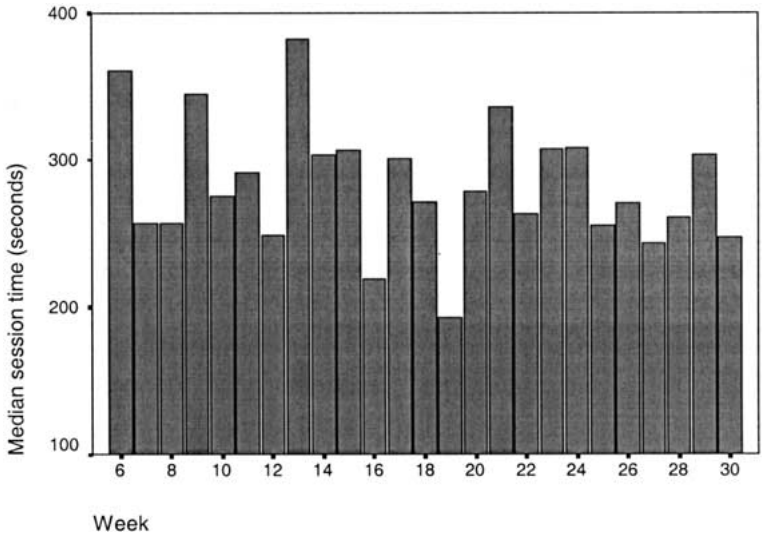

Figure 8. Median session times over the year (seconds).

educators through the communication facilities provided. This tendency towards passive use of courseware websites has also been observed by others (Comunale *et al.*, 2001–2002; Peled and Rashty, 1999).

4.3. What time did students spend at the site?

The time students spent accessing the WIER website and its different resources provided another view of their learning behaviour and also gave indications of resources that they found useful. To gain a realistic view of time students spent at the site, only sessions during which the students were continuously engaged were considered. Determining this required analysis and preprocessing of the data and is detailed elsewhere (Sheard *et al.*, submitted). This process eliminated any sessions for which the students were not active, as determined by a time lapse between activities of more than 600 seconds.

The overall median session time on the WIER site was 280 seconds (4 minutes 40 seconds) and the mean was 540 seconds (9 minutes). Considering that students accessed WIER almost twice a week, on average, this indicates that half the sessions each week were less than 9 minutes and the students spent, on average, 18 minutes at the site each week. The median session times on the WIER website over the course of the year are shown in Figure 8 and provide indications of changing work patterns. To determine any trend in times, the year was divided into three 9 week periods and the median times for these periods were compared. The median session times for these periods showed a decrease in session time over the course of the year. A Kruskal–Wallis[3] test showed that these

[3] Kruskal–Wallis is a nonparametric equivalent to one-way ANOVA.

Table 2. Mean and median times for tasks with maximum activity times of 600 seconds

Resource (Page Category)	*N*	Access times (seconds)	
		Mean	Median
Home Page	21898	51	22
Time Tracker	12115	252	95
File Manager	3315	209	99
Document Templates	1575	42	18
Risk Lists	1361	147	87
General Information	1000	63	23
Group Forum	801	138	64
Group News System	741	76	41
Calendar of Events	596	65	23
Past Projects	438	91	20
Discussion Groups	403	138	69
Resource Search	291	26	12
Administration	201	32	21
Surveys	81	105	64
Overall	44816	123	36

differences were significant ($\chi^2(2) = 7.64$, $p < 0.05$). Examining the trends in times for particular activities defined as low interactive activities (navigating, scanning, browsing and reading) or high interactive activities (manipulating information) as a percentage of total time spent at the site showed that students spent increasingly less time engaged in low level interactive activities ($\chi^2(2) = 81.9$, $p < 0.05$) and increasingly more time on higher level interactive activities such as time recording and file management ($\chi^2(2) = 64.7$, $p < 0.05$) over the course of the year.

Further information can be gathered from the times students spend using different resources. The median and mean access times for each resource were calculated as shown in Table 2. The median times varied from 12 to 99 seconds, however the mean times were generally 2 to 3 times longer. When interpreting these times the type of resource and the particular activities being performed must be taken into account. The very short median access times for resources such as Document Templates, General Information, Past Projects and Resource Search indicate that access to these resources was often just scanning, browsing or reading. The short access times in the case of the static resources of Document Templates and General Information could also indicate the students were printing this information with the intention of reading it later. The longest median times were for the Time Tracker and File Manager, indicating that access to these resources often involved more complex activities, for example entering project task details and uploading files.

Differences in access times to the WIER site and the various resources were shown between different groups of students. The median session time for females was 340 seconds compared with 251 seconds for males. The female students spent more time using

every resource, except for the Calendar of Events, and in most cases Mann–Whitney U[4] tests showed these differences were significant. There were also differences in the times the high achieving and low achieving students spent accessing resources on WIER. The median session time for the high achieving group was 301 seconds compared with 245 seconds for the low achieving group. The high achieving students spent more time on the project management resources of Times Tracker and File Manager, and also the General Information. However the low achieving students spent more time on the resources provided for extra support for their project work, the Document Templates, Past Projects and the Groups Forum. Mann–Whitney U test showed these differences were significant.

In summary, the time spent using a website another view of student learning behaviour, and, as for resource usage, can be used to make some inferences as to the usefulness of resources and learning outcomes. The resource usage patterns of the WIER website show that students usually did not spend long on sessions or very long accessing any resources, and most of their time at the site was spent accessing the Time Tracker or File Manager. The comparison of times provides further evidence that the students' usage of the site was task directed, using only the necessary or useful tools and not using it as a collaborative learning environment. This also suggests that the use of the WIER website fits more within Harmon and Jones (1999) third level of website use (Essential) rather than the fourth level of use (Communal).

4.4. What resources did students value?

Measuring the frequency of access and access times to the WIER website provided a view of student use of the site and indications of resources they found useful; however, their explicit ratings of the usefulness of the resources, determined in two surveys, enabled verification of these interpretations. Survey 1 (cf. Table 3) was an on-line survey held from week 9 to 12 and had a response rate of 44%; Survey 2 (cf. Table 4) was a paper-based survey held at the end of the IE project work and had a response rate of 89%. For each survey the students were asked to rate the usefulness of resources provided on the WIER site. The students rated each resource on a 5 point Likert scale, where $1 = low$, $5 = high$. The mean values were compared to the neutral mid-point value using one sample t-tests. The mean values for most of the usefulness ratings of resources were significantly above 3, indicating a tendency towards finding these resources useful.

In Survey 1, during the formative stage of the evaluation, the students indicated that the most useful resources were the Document Templates, Calendar of Events, File Manager and News Items and the least useful were the Group Forum, Discussion Groups and Time Tracker. Their ratings are consistent with the amount of usage of these resources at this stage of their IE project work (refer Figures 5 and 7). One exception, however, was the Time Tracker. All students were required to use this resource regularly to record their times, which explains the high usage. However, the low usefulness rating perhaps indicates

[4] Mann–Whitney U is a non-parametric statistical method used to measure the difference between the means of two groups.

Table 3. Students' ratings of usefulness of WIER resources from Survey 1

Resource	*N*	Mean	SD	*t*
News Items (from Home Page)	76	3.3	1.2	2.17*
Time Tracker	77	3.1	1.5	0.86
File Manager	77	3.3	1.4	2.12*
Document Templates	76	3.5	1.5	3.01*
Group Forum	76	3.0	1.2	0.20
Group News System	76	3.2	1.1	1.69
Calendar of Events	77	3.4	1.4	2.43*
Past Projects	76	3.2	1.4	1.28
Discussion Groups	75	3.1	1.1	0.51

* $p < 0.05$. Note: The one sample *t*-test is measured against the mid-scale value of 3.

Table 4. Students' ratings of the usefulness WIER resources from Survey 2

Resource	*N*	Mean	SD	*t*
News Items (from Home Page)	133	3.4	1.0	4.01*
Time Tracker	151	3.9	1.1	9.59*
File Manager	142	3.4	1.2	3.67*
Documents Templates	149	3.9	1.0	11.23*
Risks Lists	148	3.1	1.2	0.92
General Information	148	3.9	1.0	10.30*
Calendar of Events	155	3.7	0.9	9.01*
Past Projects	140	3.1	1.2	0.58
Discussion Groups	123	2.7	1.2	−3.34*
Resource Search	135	2.8	1.2	−2.06*

* $p < 0.05$. Note: The one sample *t*-test is measured against the mid-scale value of 3.

that the value of this resource was not apparent to them at this stage of their project work. This also indicates that usage is not always is not a good indicator of usefulness.

By the time of Survey 2, at the summative evaluation, the students had the opportunity to use all aspects of WIER over the full lifecycle of their IE project work and allows comparison with their overall usage of the resources. These survey results present a different picture to the earlier survey, however their ratings of usefulness were generally consistent with usage. The students indicated that the News Items, Time Tracker, File Manager, Document Templates, Calendar of Events and General Information were the most useful facilities. These are all related to critical tasks for their project work and, with the exception of the Calendar of Events, were used extensively. They rated as least useful the Past Projects, Discussion Groups and Resource Search, which they had used the least. In considering usage as an indicator of usefulness, an anomaly was the Risk Lists, which was not rated as useful, and, as for the Time Tracker in the first survey, the high usage was most likely because the resource was mandatory. Feedback from staff verified that the Risk Lists resource was poorly used by the students who were not able to assess what events could realistically impact on their project and take the appropriate counteracting measures.

Table 5. Usefulness variables producing a significant impact

Resource	Standardised Beta	t	Significance (p value)
Time Graph	0.285	3.876	0.00
File Manager	0.320	4.585	0.00
Risk Lists	0.192	2.626	0.01
General Information	0.267	3.877	0.00

4.5. Effectiveness of resources provided by the site

The main purpose of the WIER website was to provide support for project management. The students were asked to rate the effectiveness this support using a 5 point Likert scale, where 1 = *low*, 5 = *high*. A mean value of 3.5 was obtained which was compared to the neutral mid-point value using a one sample t-test. The result was significant ($t(151) = 5.74$, $p < 0.05$) indicating a tendency towards finding the site effective for project management.

The relationship of the influence of the students' Survey 2 ratings of the usefulness of WIER resources on their valuation of its support for project management were investigated using a stepwise regression.[5] Seven of the ten usefulness variables that produced coefficient values greater than 0.3 when correlated against the support for project management were used in the regression. These variables were regressed against the support for project management, producing a model with an R^2 of 0.44, significant at $F(4, 122) = 24.28$ for $p < 0.05$. Four variables produced a significant impact as shown in Table 5. It is interesting to note that these are also the resources that had the highest usage, indicating that the students' use of the site was fulfilling the educators' intentions.

5. Implications of Findings

When providing a Web-based learning environment for their students, educators generally have expectations for its use; however, often the educator model does not match actual usage. The students may use resources at different rates or for different times, or for purposes other than those intended by their educators. A course website is typically complex and there are various determinants for course website usage. There may be issues with accessibility or usability, or the students' usage of a resource may depend on its usefulness. To provide an effective learning environment, it is important that educators know and understand how their students use them. The aim of this study was to explore what information can be gained from analysing student interactions with Web-based learning environments and the value of this process in providing information to educators.

The WIER website used in this study was designed to provide students with access to tools to use for project management and support materials for their work in their industrial

[5] Regression is a technique that estimates the linear relationship between a dependent variable and one or more independent variables.

experience projects. This formed an integrated environment with static and dynamic resources that had a range of interactivity. The site provided resources for individual use and to facilitate group work. Students were required to use a couple of the resources on the site for their IE project work, however most were optional.

If we look at the information gained from analysing student interactions with the WIER website, some learning behaviour could be determined from exploring their use of the site, providing information that is difficult to obtain by other methods. The frequency of access and time spent at the site gave insights into student work patterns on a daily and weekly basis, and over the course of their project. This information is useful for monitoring use of a site to determine whether students access resources at appropriate times and frequencies thus allowing educators to make adjustments to the teaching program. For example, access to the Time Tracker on the WIER site indicated that many students were accessing this resource fortnightly or less rather than weekly. Regular recording of project times is an issue with some students and formative reviewing of student interactions could enable automatic reminders to students to enter their times.

The impression gained from the usage of the resources, in terms of both frequency and time spent, indicated that the students found the functional resources the most valuable; correspondingly, they found the communication resources least valuable. The inferences made from the students' interactions with the site were that their use of the website appeared to be largely determined by what was essential for their work in their course. Students were very much driven by critical project tasks and assessment and did not engage with the site beyond what was necessary. They did not show much evidence of wishing to contribute to the site in terms of the discussion facilities or contribute to the resource repository. These interpretations of their interactions were supported by the results of the surveys. Although indications of the usefulness of a resource can be gained by measurements of usage this can also lead to a misleading impression of the value of a resource. The meaning of the term 'useful' is interesting to explore. We could imagine that some students would tend to rate as most useful resources that they used most frequently, as these would be most salient in their thoughts. An important resource might be one that they used only once, for example, Document Templates, but they may not rate this as highly 'useful' in comparison to the File Manager, which they used constantly. In looking for indications of usefulness from interactions it is therefore important to consider the type of resource.

Determining the time spent using a website gives another view of student learning behaviour. The mean time spent per week using the WIER site was approximately 18 minutes and we consider this a reasonable time to spend using a project management facility. However, the use of the website varied between students and it was interesting to find female students used most resources more frequently and for longer periods than the male students as this was contrary to findings in the study of website usage by Peled and Rashly (1999). This has confirmed an impressionistic view that the female students usually take administration roles within the groups and are often responsible for the documentation rather than the more technical tasks. These allocations of project roles have sometimes been found to be inappropriate and this has encouraged us to review the role allocation processes within the groups.

Analysis of usage of a website can also gave indications of its value to students for their work. Comparisons of the WIER website usage showed that the high achieving students had more interactions with the site than the low achieving students. Furthermore they had more interactions with each of the key project resources. The greater use of the core resources by the high achieving students may indicate the benefits of regular use and the value of these resources for a successful project outcome. However, it also highlights a difference in work practice between these two groups of students. As an example, the greater engagement with the Time Tracker by the high achieving students appears to indicate a more thorough and explicit analysis and recording of the details of their project work. Whereas the higher use of the resources such as the Document Templates and Past Projects by the weaker students indicates that they may have been seeking extra support and this suggests that providing further resources such as an anonymous feedback facility may be valuable for them. Monitoring student use of particular website resources could be used by educators to determine students who are having difficulty with their work or at risk of not achieving a successful outcome.

The complexity of tertiary courseware websites and the variations between teaching programs means that it is difficult to compare usage of websites in a meaningful way. Furthermore, a search of the literature has shown a scarcity of detailed usage analyses of courseware websites and therefore there are no benchmarks to use. However comparison of usage of resources within a website as determined by interactions provides valuable information that may be used by educators and site designers when making decisions about teaching programs, and provision of the learning environment and resources. Comparison of interactions of different student groups can provide further insights into different work patterns and indications of successful learning behaviour.

6. Conclusion

With the prolific use of Web-based learning environments in tertiary education, it is essential that educators use them appropriately. To do this they need an understanding of how they are used and valued by their students. This study provided an opportunity to determine the type of information that can be provided by analysis of students' on-line interactions. Usage patterns of the WIER website and resources in terms of frequency of access and time spent at the site provided a rich picture of student learning behaviour. Inferences made about the value of resources were verified by survey data. This showed that analysing student interactions enables a non-intrusive way of gaining information about student learning behaviour at the formative and summative stages of use. Further work will look at how individual students' learning experiences match up with data obtained from interviews and observations. This fine grain analysis will be used to determine predictors of student learning difficulties and problems with site design and ultimately this will assist in the development of a pedagogical model for on-line learning.

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