

***Technical Report No: 2000/09***

***Observational studies of student errors in a distance  
learning environment using a remote recording and  
replay tool***

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## Technical Report

# Observational studies of student errors in a distance learning environment using a remote recording and replay tool

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### Abstract

AESOP is 'An Electronic Student Observatory Project' at the Open University, Milton Keynes consisting of a set of tools written in Smalltalk allowing student's activities and progress through an on-line distance education course to be remotely recorded, replayed and analysed. The following paper outlines some initial findings from observations made on a cross-sectional group of 368 volunteers taking the course in 2000. Students observed to be using low resolution 640 x 480 screens were noted as taking significantly longer to complete on-line course work ( $p=0.018$ ). No differences were observed between age groups taking part in the study, but some gender differences were found with females reporting being less comfortable at using computers and that males used a greater variety of central processing units. Some evidence indicates that female students were also more likely to be using lower specifications machines than males. Differences noted between genders in RAM and screen size specification of the machines used by the students were found to be just outside significance level.

### Introduction

Since the development of computing technologies and particularly the advent of the World Wide Web (WWW) there have been increasing efforts to take advantage of the benefits these technologies can bring to teaching. These include improved methods of course delivery combined with a rich multi-media environment aiding the pedagogical effectiveness of the material as well as improved access; both for those who already have access and for those who would otherwise normally be unable to undertake the various studies. There is also perhaps an element of wanting to be seen to be keeping up with the times and in the United Kingdom at least, pressure to exploit the new technologies available (Smithers, 2000; Sutherland, 2000).

Considering the wide variety of computing hardware that the general user has available to access these technologies, a major issue is accessibility and delivery of web based teaching or web based instruction (WBI) (Chisholm et al., 1999). However in addition to accessibility issues, there have been a number of areas identified which web content developers need to be aware of that can affect the pedagogical effectiveness of on-line teaching material. The main areas of concern include the display fonts used, screen size and resolution, use of multi-media, seductive details, quality, layout and navigational design issues.

#### ***Display Font, Screen Size and Screen Resolution***

Kingery and Furuta (1997) looked at electronic newspaper headlines and compared the onscreen typefaces (fonts) of Times New Roman, Arial, Century Gothic and Book Antiqua under the various factors of point size, screen resolution and screen size (14 inch and 19 inch screens). They found that interactions existed between all these factors and that best overall legibility was achieved by using either Times New Roman or Arial which are specially adapted for the display of text on the computer screen. Earlier work by Gould et al (1987; 1987) tried to identify the factors that influenced reading speeds when using cathode ray tube (CRT) displays and showed that reading speeds equivalent to reading from paper could be achieved, but this was dependent on the image quality on the screen. They tentatively concluded that display polarity, resolution and anti-aliasing

(Boersma, 1999) each contributed to the elimination of the paper/CRT reading speed difference. While some designers may not regard this of much concern considering the availability of modern large high resolution screens a recent survey of over 2000 distance learning students (Kirkwood and Rae, 2000) showed that the variety of computing equipment available and being used by distance learners at least is huge and a small but significant proportion still use low resolution small screens. In addition, some users because of visual impairments prefer to use low resolution screens (Chisholm et al., 1999), and a few users are unaware of that they can change screen resolution or screen default font size (Clover, 2000).

Fleming and Levie (1993) highlight the problem that less text can be displayed on a computer screen than on a typical page and that to compensate designers need to condense information so that more information is available on each screenful. As a method of putting more information on the screen and organising in a meaningful way, information mapping and other methods of chunking data have become a popular topic of discussion amongst other issues with educational web content developers such as those found on the Instructional Technology Forum (*ITFORUM*) and Educational Technology (*EDTECH*) discussion groups. However this raises accessibility issues, including the use of the hyper text markup language (HTML) table attribute which the W3C group recommend is used only for table and data presentation and not for screen layout because it makes it difficult for the screen readers used by the visually impaired to interpret the screen content (Chisholm et al., 1999).

### **Seductive Details**

In another aspect that affects both printed and on-line material Garner et al (1992) and Harp and Meyer (1998) focus on the use of what has become known as ‘seductive details’: items of information that may or may not be topically relevant that have been included to spice up text which readers might otherwise find boring. While the function of such bits of text is to try and hold the readers attention, it has been found that unless used in the right way they often have detrimental effects. The effects include poorer retention of information and interference with transfer performance tasks. Harp and Meyer in the course of their investigations found the only place they could put seductive details with no detrimental effects was after the text needing to be learnt.

Although the above studies on seductive details looked at text inclusions with paper based material, the use of computers allows a lot more opportunity for web content developers (authors and designers) to take advantage of other forms of media as well as multi-media. However it appears no studies have been done that investigate possible seductive detail effects in the use of alternative media’s such as audio, static graphics or video, or even in multi-media when two or more of these are being used together. Studies in the use of multi-media (but not the seductive detail effect) have been done.

### **Use of Multi-media**

Studies in the use of multi-media include work by Mousavi et al (1995) and Mayer (Mayer and Sims, 1994; Mayer, 1997). Sweller (1988; 1989; 1993; 1994) suggests in his ‘Cognitive Load Theory’ that many common instructional procedures are inadequate because they require learners to engage in unnecessary cognitive activities that impose a heavy load on working memory. That is, we all have a finite amount of working memory (after Baddeley (1992)) available to us. Mousavi *et al* in their findings on presenting material via auditory and visual media at the same time argue that the effect of the Cognitive Load Theory is reduced if information is presented in a physically integrated format that reduces the load on working memory.

Further support for concurrent presentation of audio and visual material comes from a later review of similar studies by Mayer (1997). In which he found there was consistent evidence that students who were presented with co-ordinated material generated a significantly higher number of creative solutions in problem-solving transfer tests. He also found that in accordance with his 1994 study (Mayer and Sims, 1994), multimedia and concurrent presentation effects were strongest for those

with low prior knowledge and high spatial abilities. Mayer argues that presenting text (visual) and animation together means the learners visual attention has to be split between the two which could cause visual attention to become overloaded and lose some of the information. However, the inclusion of text or an alternative form is recommended by current accessibility guidelines to allow those with no multi-media capable machines or those with hearing difficulties to still be able to access the material (Chisholm et al., 1999).

Most of the previous studies however used laboratory based experimental methodologies to study the effects of the different attributes being investigated. While this provides a controlled experimental situation, it by definition controls for the effect of factors that possibly could influence the outcome and not all of these factors are known or even possible to reproduce under experimental conditions. To address this issue in relation to students studying distance learning material at home, the AESOP study outlined here is an observational exploratory study that allows detailed observation of subjects using on-line expository material to be carried out remotely at a distance.

A problem with studying students using on-line expository material in day to day situations is both possible bias from the experimenter just being present (Good and Watts, 1989), but also the degree to which the input / output could be recorded accurately. In the laboratory or in users' homes, experimenters can and do use video cameras to record all interactions with the computer. However this has limited functionality requiring data to be recorded by hand from the replayed video tape, provoking other more suitable methods to be sought. The idea of using this type of recording tool, that is an application designed to work in the background capturing data, for observation is not new (Card et al., 1983; Smith et al., 1991; Smith et al., 1993; Kivi et al., 1998) and there are similar applications available to the general public for example Bergeron's Picture and Key spy (Bergeron, 2000a; 2000b). However past problems have been limited functionality for research purposes, either recording not enough, or too much of the information required. Recording graphics presents its own problem requiring large amounts of memory to store the image files: something which can be arranged in an experimental laboratory, but impractical when studying using the subject's own equipment, which may not have the resources to do so.

The following sections describe the use of a remote recording and replay tool specifically designed for the remote observational study of subjects' interactions with a computer and present some preliminary findings from the observations.

### **Outline of the study**

AESOP is *An Electronic Student Observatory Project* (<http://mcs.open.ac.uk/AESOP/>) (Thomas et al., 1998a; 1998b; Thomas and Paine, 2000b; 2000c; 2000a), at the Open University that consists of a collection of software applications for recording, replaying and automatic analysis of recorded data. AESOP has been built around the Open University's distance education course *M206 Computing: An Object-Orientated Approach* (The Open University, 1998) which teaches amongst other things the Smalltalk object-orientated language (OOL) language and concepts involved in OOL and networking. Central to this is the LearningWorks Smalltalk environment (Goldberg et al., 1997; Woodman, Griffiths, Macgregor and Holland, 1999; Woodman, Griffiths, Macgregor, Robinson et al., 1999) that is used to deliver the computer based practical content of the course.

Observation of students' interactions is carried out using two applications, the 'recorder' and the 'replayer'. Further data comes from two on-line web accessed questionnaires.

#### **Recorder**

The Recorder consists of two small application files that students participating in the study are able to download and install onto the machine they have Learning Works running. In order to minimise the need for users to interact with it the recorder has been designed to launch automatically and invisibly start recording whenever a student opens up a LearningBook (LB), a set of computer

based practicals organised into chapters. It does not record anything outside the Learning Works environment when in use, but records to a text file those events occurring within each LB which have been defined by the AESOP team as being of interest. These include opening and closing of LBs, opening, selection, movement and resizing and closing of windows, scrolling, button clicks, hyperlink selection and evaluation of expressions (Smalltalk program code entered by the student). In addition, each individual event is time stamped. A new file is created for each LB that is opened, but if a LB is closed and then reopened at a later time the Recorder appends any new events information to the original file.

An example of the text output from the recorder can be seen in Figure 1. The output is designed to be easily read by a human evaluator and many lines in Figure 1 are clearly related to window manipulation and hyperlink usages (lines beginning with enter, tab, scroll for example). Other lines represent user interaction with the LB as noted in the figure.

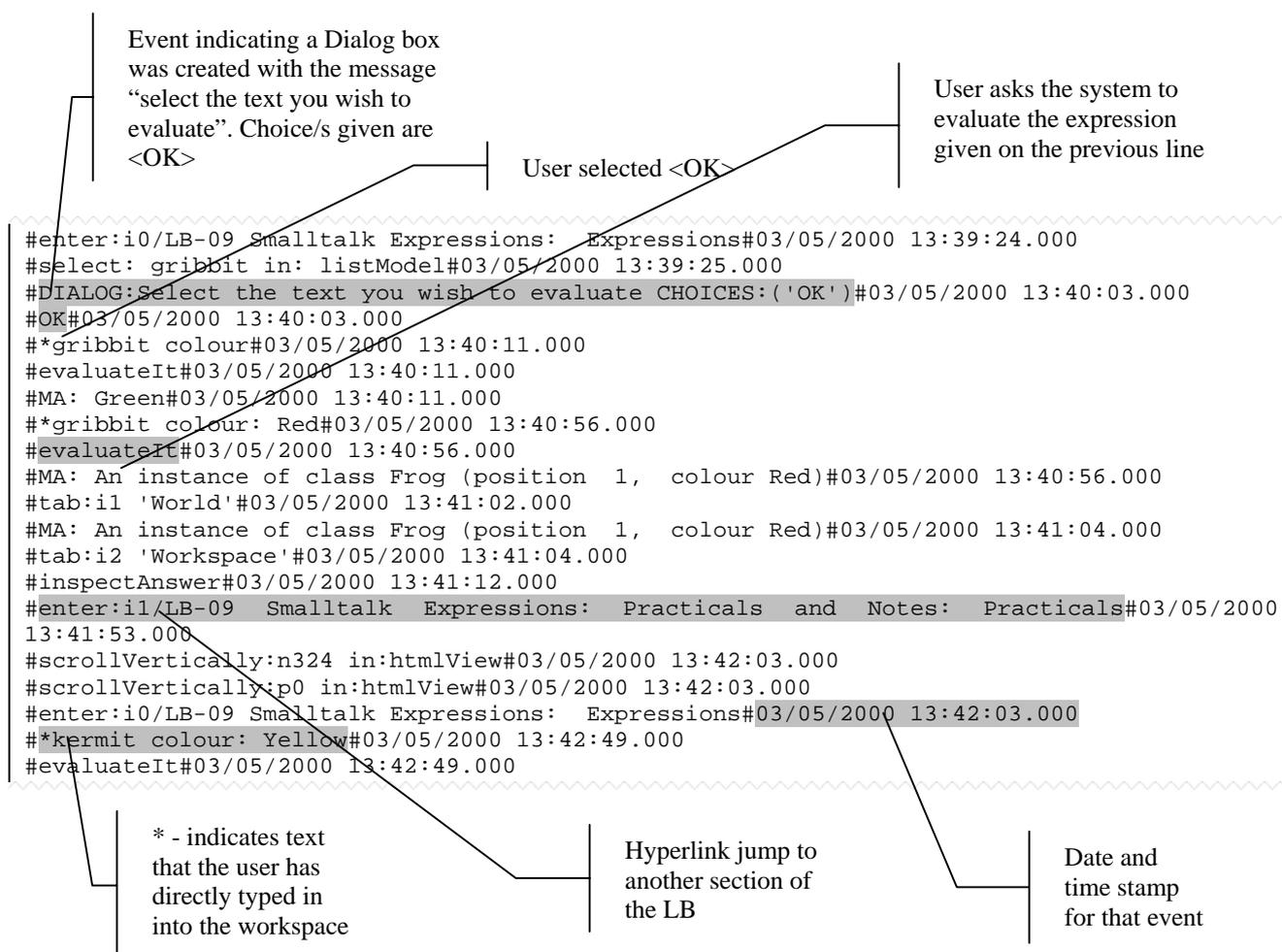


Figure 1: Sample of text record made by the Recorder tool. Taken from an actual student's submitted record. Some areas highlighted to show some features.

One of the advantages of this system is that being text the file sizes are not large and students who are distance learners working in their own time at their own pace can choose when to return the recordings. These are returned as email file attachments.

### Replayer

The Replayer was developed to assist in the observation and analysis of users' actions. The tool effectively allows the text recording created by the Recorder to be transcribed from text back to visible actions on the Learning Works graphical user interface as it would be viewed by the user

who created it. This includes replaying all significant events including window selection and resizing. The text record is also presented in a scrollable resizable separate window so that the line of text or command being carried out is by default highlighted and centred in this window. As the original text record has one instruction to each line, the Replayer can carry this out in a 'frame-by-frame' or 'line-by-line' step-wise fashion or continuously at a set pace controlled by a sliding scale. The ability to manually edit text files and add a stop command gives further functionality to the Replayer, allowing files to be replayed at high speed effectively fast forwarding them to the point at which the stop was added and then replayed at a more convenient speed to view and analyse the user's actions.

The advantage of replaying text files in this fashion where students are adding new programming code is that the Learning Works system automatically adds any new objects or code created by the student to the system and will show any error messages that result from the students' input. Unfortunately this also means you cannot start reviewing the recordings from any arbitrary point.

The replay of recordings also has to be done on a screen resolution equal or better than the resolution of the screen that the original record was made on otherwise the screen placements of the active Learning Works windows will be a 'best fit' and therefore give a distorted view of what the user actually saw.

### ***Questionnaire Design***

The inclusion of questionnaires into this study was to collate and monitor information that the recorder was not designed to or would not be able to collect. Two questionnaires were created, a Pre-Study Questionnaire (Logan and Paine, 2000) designed to collect general demographic details about subjects, such as age, gender, occupation, current knowledge of computers, level of comfort carrying out various computer related tasks, as well as the specification of the computer they were using to study the M206 course, such as screen size and resolution, processor and speed and memory. This questionnaire was made available to students at the start of their studies.

A slightly longer Post-Study Questionnaire was produced to collect general data looking at problems students may have had installing and using the software, and also compare in a repeated measures design any changes from the Pre-Study Questionnaire in levels of comfort and use of computer. The Post-Study Questionnaire was made available to students shortly before their final end of course exam.

Following the design of the questionnaires both were assembled using ColdFusion and delivered via the web, sending out by email an invitation to participants in the study to access the web page the questionnaire was hosted on. The problem of accessibility was taken into consideration, but using a web interface was considered the most practical and cost effective method since web access was a pre-requisite of the M206 course. Both questionnaires were designed to be short to help maintain interest and improve response rate (Courtenay, 1978; Labaw, 1982) and be completed offline once downloaded onto the clients web browser so that further connection to the internet was only required when needing to submit the completed form.

### ***Pilot study***

A small pilot study had been carried out in 1999 (MacGregor et al., 1999), using a much smaller number of students (n=24). This highlighted some problems with the Replayer and the type of events that were being recorded leading to changes being made to the Recorder allowing greater detail to be observed while replaying students' behaviours and refinements being made to the Replayer.

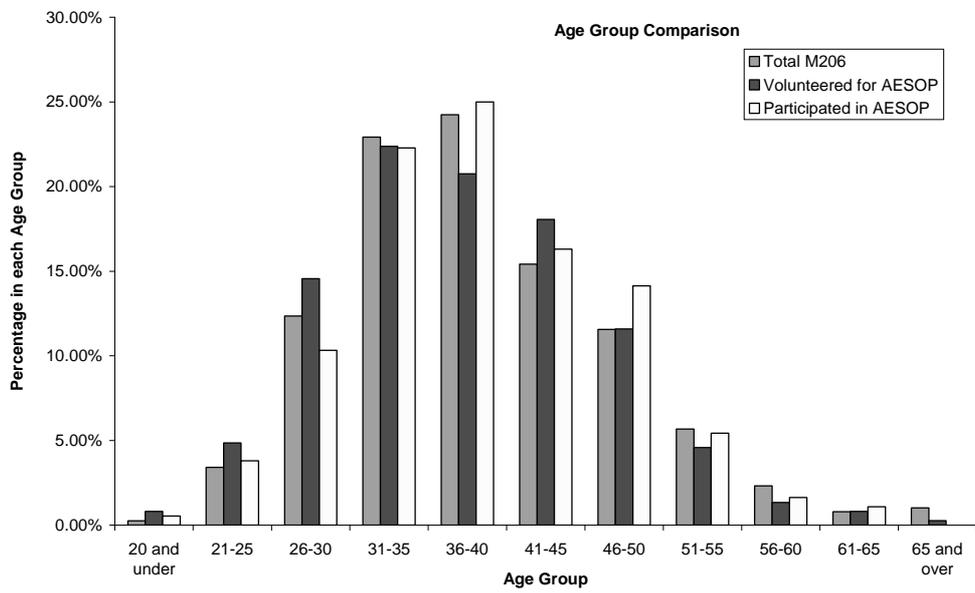
## **Subjects**

All subjects were student volunteers from the Open University's distance learning course M206. For the study on the year 2000 intake an invitation to be part of the study and to complete the Pre-Study Questionnaire was made to all students at the same time they received their course material in January (n=3399). No incentive was offered to the students other than explaining the purposes of the study. 368 students volunteered to take part, out of which 182 (49%) returned one or more recordings and of the remaining 186, 11 (3%) are known to have dropped out of the M206 course. Data regarding other reasons for not participating are still being collected from the Post-Study Questionnaire

## **Method and Results**

Because AESOP is an exploratory study it had no predetermined objectives or specific experiments in mind other than to see whether it was possible to observe student's on-line behaviour while progressing through the M206 course, at a distance and to see what behaviours and information could be gathered from a tool such as the Recorder and Replayer.

Results from the Pre-Study Questionnaire showed that both the composition of the group who volunteered at the start to be involved in AESOP (Volunteered) and the subsection of these who continued to send in one or more recordings (Participated) comprised a very good cross-section in gender and age of the students on the M206 course (see Figure 2 and Figure 3).



re 2: Comparison of volunteer group composition by age bands.

Fig

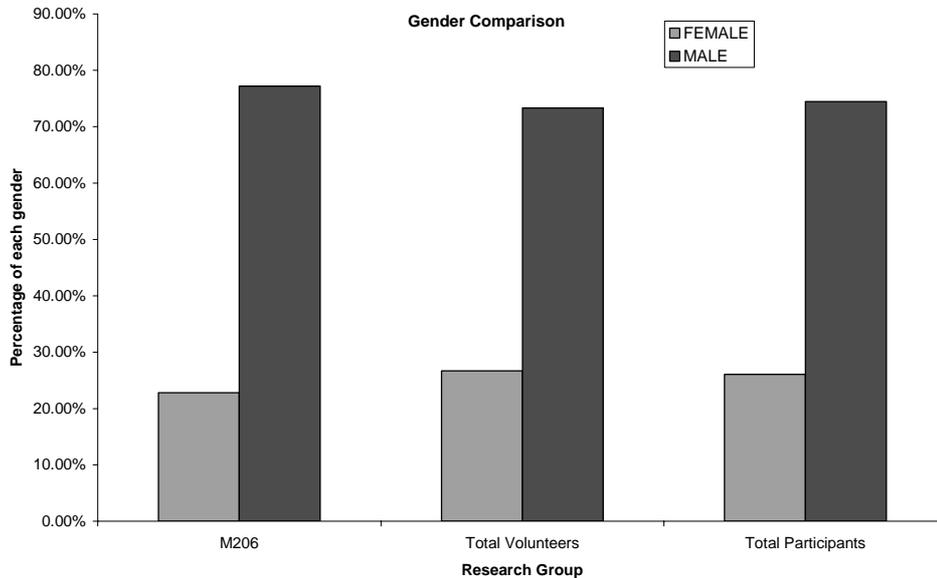


Figure 3: Comparison of volunteer group composition by gender.

Analysis of students' recordings was initially performed by reviewing by eye the individual recordings using the Replayer. However as each student had the possibility of returning a maximum of 24 LBs and the average time to review a record being well over an hour, it became an impractical proposition to review 4368 records by hand in the time frame available. Because of this more effective and automatic methods of reviewing the data were sought. This led to the development of the Analyser consisting of a set of tools that are capable of automatically editing, filtering and analysing the records individually or as a group.

Casual examination of the data available indicated that at least two main areas of behaviour could be explored; analysis of time and study patterns and analysis of students' errors. All records could be used to analyse the study patterns and times, these being derived from the automatic date and time stamp appended to each recorded event. However as with most observational studies, the presence of errors made by students and their subsequent actions as they correct them also provides a convenient insight into the possible cognitive processes involved and the factors that may have influenced the students into making the errors.

The results are being combined with the data from the pre-study and post-study questionnaires and some early findings have emerged. One of these is the diversity of equipment being used by students for their studies and a notable proportion of students using low-resolution screens (640x480).

### **Screen Resolution Vs Time to Complete Work.**

As well as studying the various ways students arranged their open LB windows at the various screen resolutions, the influence of screen resolution on the time taken to complete a LB was also analysed. However simple observation showed that students were found to be inactive for long periods of time. That is the time gap between one recorded event and the next could occasionally be anywhere up to several hours (22.5 hours in one case!). Unfortunately in general during these periods there is no way to tell whether the students have left for a break or are using the paper based course material. A compromise was sought and found by using the Time Tool (Thomas and Paine, 2000b) one of the tools which had been developed to automate the analysis of the recordings. Using the Time Tool a separate set of figures for the total time taken to complete the LB was produced for each LB with all the time gaps between two successive events that exceeded 5, 10, 15, 30, 60 and 120 minutes removed.

For the purposes of this analysis the total time to complete a LB with all breaks exceeding 5 minutes removed was used as it had been shown that this produced the least variance over all the LB times and effectively was the “Total time actively spent working on the LB” (total active time – TAT). In addition only the later LBs were studied, starting at LB 9 as this is the first LB where students are given the opportunity to evaluate program code; earlier LBs are primarily involved in orientation and learning about the graphical user interface, where there was no opportunity to observe errors. It was also felt that by the later LBs students would have settled into their working environment and developed a fairly regular working pattern.

Analysis was carried out using SPSS<sup>®</sup> to compare the mean total active time of each LB under the various screen resolutions being used. Box plots of the distribution of TATs for all LBs analysed showed that students using a screen resolution of 640 x 480 took longer to complete LBs (Figure 4) and this was shown to be significant ( $p=0.018$ ). Later LBs (that is after LB12) also showed a similar but less pronounced trend, which was not significant. This may be because these LBs are used for tasks which are less structured and therefore users show a greater natural variation in the times they take to complete them, regardless of the screen resolution.

Another concern is that the data about the screen resolution comes from the Pre-Study Questionnaire, which was matched against the individual’s subsequently submitted records. While there is no way of really knowing whether students changed their screen resolution during their progress through the course, this does not seem to be case as replayed records show the placement of student windows consistent with a 640 x 480 screen resolution as opposed to a 800 x 600 screen resolution or greater (See Figure 8 and Figure 9 for an example).

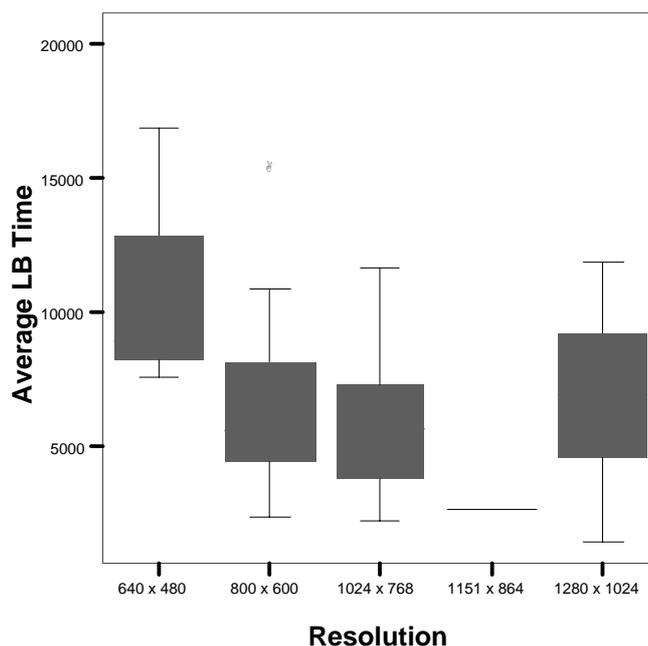


Figure 4: Box Plot showing distribution of average Total Active Time (TAT) taken to complete LBs 9, 10 and 12 (in seconds), against screen resolution used by students. Those using a 640 x 480 resolution took significantly longer to complete early LBs ( $p=0.018$ )

### Pre-Study Questionnaire Analysis

Data from the Pre-Study Questionnaire was also analysed independently of the data gathered from the Recorder, looking for any differences apparent between ages or gender in the following areas:

1. The extent to which students used computers prior to the course and for what types of activity.

2. Level of comfort that is displayed carrying out various computer related tasks.
3. The hardware configuration of the computer being used to study the course.
  - a. Screen sizes used.
  - b. Screen resolutions used.
  - c. Type of processor being used.
  - d. Clock speed being used.
  - e. Amount of system RAM.

Apart from determining any demographic differences the purpose of looking for these variances was to aid in the classification of student errors and try and determine any factors which may be influential to the formation of such errors. Age in all the factors investigated showed no significant trends. However some gender differences were apparent in some areas.

Students were asked to estimate how much time in hours they spent carrying out various tasks on a computer on a weekly basis. No differences were found between male and female students on virtually all the tasks except in the use of the internet in which males estimated spending significantly more time than females ( $p=0.003$  males mean = 6.89 hrs/wk, females mean = 4.17 hrs/wk.)

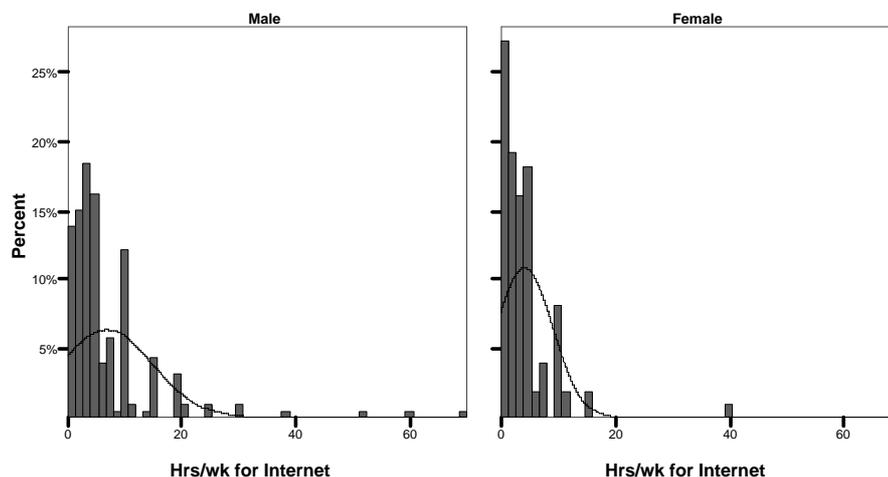


Figure 5: Histogram comparing female and male distance learning students estimated use of the internet in hours/week, prior to course commencement. Curve displays calculated normal distribution.

Students were also asked on the Pre-Study Questionnaire to estimate how comfortable they were carrying out the following various computer related tasks: installing programs, using applications, using email, using the internet and programming on a five point scale. Females responded as being less comfortable in using or carrying out the various tasks than males and this difference was found to be significant for all tasks with the exception of using email. The mean of each student's expressed level of comfort across the five categories was also calculated and compared by gender using an independent t-test, the difference between males and females was found to be highly significant ( $p < 0.000$ ). Figure 6 shows a histogram of the mean expressed levels of comfort for each gender where 1 indicates being totally uncomfortable ("Not at all comfortable") and 5 indicates being totally comfortable ("Very comfortable").

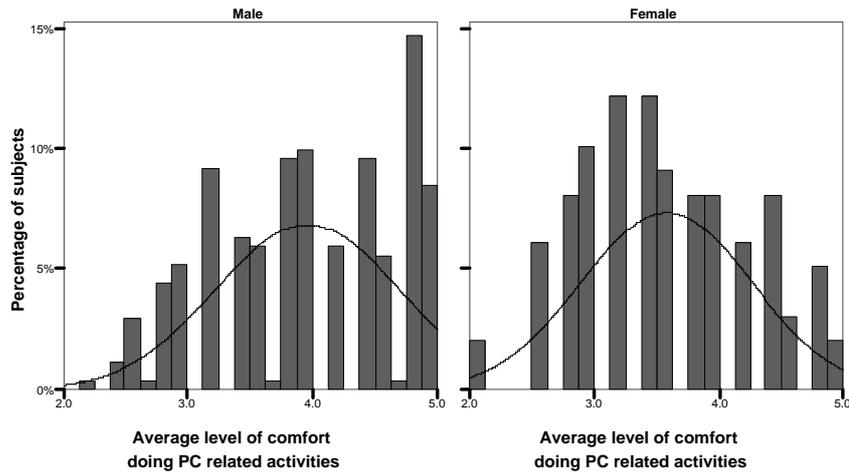


Figure 6: Mean level of self-reported comfort across various common computer related activities. Curve displays calculated normal distribution.

A comparison of the hardware configurations between genders in the study, looking at processor, RAM, clock speed, screen size and resolution appeared to show a general trend for females to be using or to have access to less powerful machines for their studies. Some support for this comes from differences in screen size and RAM, but both measures were found to be just outside the 5% level of significance (screen size  $p=0.06$  and RAM  $p=0.053$ ). A significant difference however was found between males and females in the range of motherboard chips in the machines, with males more likely than females to be using processor chips made by manufactures other than Intel ( $p=0.002$ ). It would also appear that females tend to use older less powerful Intel chips indicating that the machines they use are older.

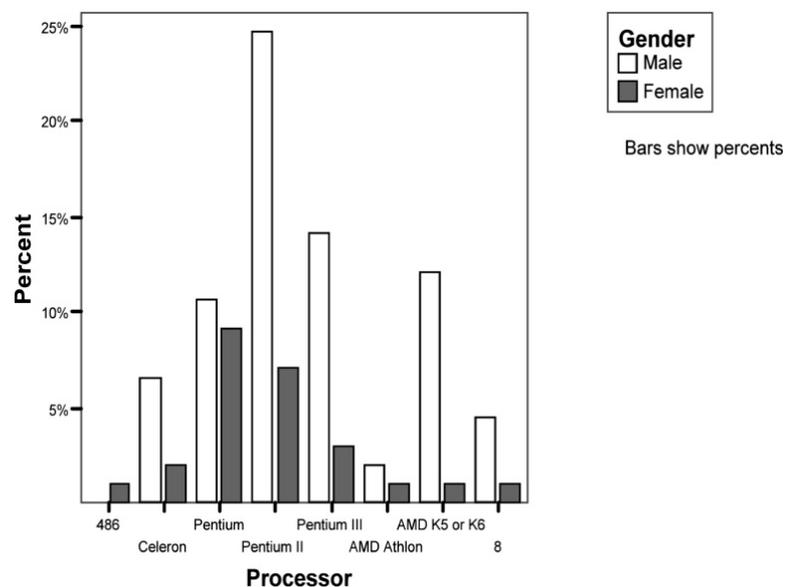


Figure 7: Histogram showing the variation in the motherboard chips of the computers used by students. (Category 8 = other).

## Discussion

On the basis that those who volunteered to take part in AESOP comprise a representative sample of the total body of students studying the Open University's distance learning course M206 in 2000, the results appear to indicate that although there is no discernible differences between age groups taking part, there are differences between the genders. The evidence in this study although not strong, suggests that female students tend to use computers that are older or less powerful than the

ones used by males for their studies. However there is a significant difference in the levels of reported comfort for various computer related tasks between males and females, with females in general reporting being less comfortable. What impact either of these differences may have on student's progress has yet to be determined and is currently part of the work in progress. Although it cannot be ruled out at this stage that males falsely report their level of comfort performing various computing related tasks, it will be interesting to see if the difference between male and females is still present at the end of the course or whether there has been a discernible shift in attitude.

Of particular interest was the finding that students using low resolution 640 x 480 screens were significantly slower completing LBs, spending a greater total active time carrying out the tasks requested. The use of slower machines was considered, but data on the configuration of these computers indicated that users of low-resolution screens tended not to have older slower equipment or to have screens that could not support a higher resolution. The average machine used by these students being a Pentium II and many also had 17 inch (in one case a 19 inch) screens. It is possible following on from the work by Kingery and Furuta and Gould et al, discussed earlier, that these users of low resolution screens took longer because of slower reading speeds. However, there were no appreciable differences in the times taken by those using low-resolution screen and those using a higher resolution to read a block of text. In addition to which the actual height of text characters for users of low-resolution screens was in fact greater than for higher resolutions, which would aid reading speed not hinder it. This is because a feature of LB windows is that they open up at a set dimension, not a relative one, so on a 640 x 480 resolution the LB window and text is larger than on a 800 x 600 screen of the same dimensions.

However it was found that users with low-resolution screens frequently had to switch windows in order to see the contents. This was because of another feature of LBs in that an open LB window could be enlarged but not made any smaller than the size it opened at (although it could still be minimised to the windows task bar). Each LB is presented initially as a single open window with several clickable tabs, each accessing a different section that can be detached and made into a different window. Following course instructions users would typically detach the on-line text and place it as a separate window alongside the workspace so they can see the text at the same time. On a 800x600 resolution screen users can see both text and workspace windows side by side with little overlap (Figure 8). However because the minimum size of an open LB window is absolute not relative, on a 640 x 480 screen the overlap is considerable enough that the only way users can see both text and workspace is to swap between windows (See Figure 9 for example of screen layout at 640 x 480 resolution).

Analysis of the records showed that users of low-resolution screens were switching between windows almost twice as many times than users of higher resolution screens. Considering this has to be done manually either by mouse or keyboard both of which take time to be done physically we believe it to be a major factor affecting the speed at which users of low-resolution screens take to complete LBs.

Switching between windows however, does place a greater load on working memory since the user has to remember the information that was in the previous window. This takes up working memory resources and as a result leaves less working memory available for the cognitive tasks of selecting, organising and integrating involved with the process of learning (Sweller's "Cognitive Load Theory"). It is possible therefore that another reason why users of low-resolution screens take longer to complete work is because more time is required to cognitively process the information. The other implied consequence of this is that because these users have less working memory available to process the material to be learnt, they may perform less well than others in assessments and is an area of possible future research.

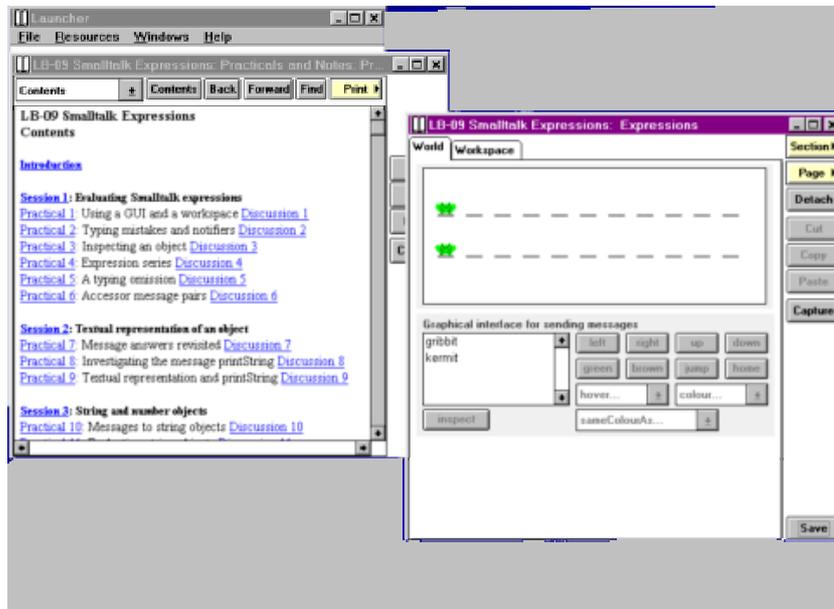


Figure 8: Example of a typical LB screen layout by users using a 800 x 600 resolution screen.

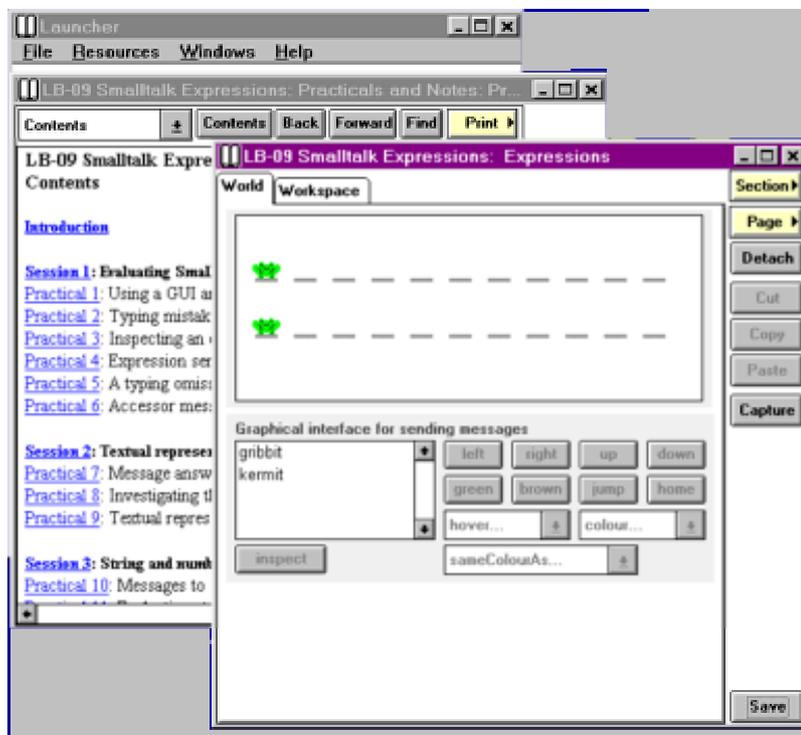


Figure 9: Example of a typical LB layout by users using a 640 x 480 resolution screen.

## Future Work

Future work with AESOP is to look at student errors and determine if any factors can be defined to be influential in their cause. As part of this, further work needs to be done looking at the time in which users take to complete the work, patterns of working both in time and material. That is do users complete all the material in each LB or do they just do a few exercises in each and is this related to any factors such as screen resolution, processor speed, etc.

As an observational tool the Recorder and Replayer used by AESOP has already shown itself to have major potential if adapted for observation in other applications. Addressing the major issue of being able to remotely observe and record in detail, but also recording actions to a transcribable text file so that little memory is taken up: an advantage both for transmitting information over the

internet or storing on a hard drive particularly in view of the number of older computers still in use that have limited hard drive memory. Further practical application of the Recorder is already in progress with the development of a COACH tool for the M206 course. This tool exploits the fact we have a record of student errors and how they were solved. Analysing how these errors were produced we can create a database of useful information based on student experiences and make this data available to students to give feedback, guidance and information to help them solve their problems without solving it for them. That is for a given problem or error the COACH accesses the database returning those methods that most closely match the methods other students have used in the past to solve the problem.

## Summary

AESOP was set up to allow observational studies of students at a distance using a remote recording tool and to look at the various factors that influence students as they work through the distance education on-line course material. Further data including general demographics and a repeated measures design for certain measures was gained from web based questionnaires both prior and post to the course. Although the age of student volunteers varied from under 20 to over 65 there were no apparent differences attributable to age. However differences were noted between genders with females reporting significantly lower levels of comfort about carrying out various computing related tasks, at the start of the course. Other indications are that female students also tended to use computers of lower specification than the males. The evidence for this however is tentative based on a variety of measures looking at the configuration of the computers being used and two of these measures were found to be just outside the 5% level of significance.

A diversity of computer configurations were found to be in use. Of particular interest was the finding that students who used a low resolution 640 x 480 screen, took significantly longer to complete on-line course material. It could not be assumed that this was due to slower computing equipment because some students using this resolution were noted to be using moderately fast machines quite capable of displaying higher resolutions. The extra time being taken by those using a low resolution has not been determined but could be due to a number of factors including having to manually swap between open windows, slower reading of text at low resolution and the extra cognitive load placed on working memory (Sweller's Cognitive Load Theory).

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Carina Paine

Who's individual efforts into areas of the project have taken it this far and beyond.

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