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An Evaluation of a Virtual Assessment Environment

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Abstract

This paper reports the preliminary results of a project that investigated the use of computer-based simulation to improve the validity of assessment and provide unlimited formative assessment without use of lecturer time. Specifically it aimed to develop a computer-based simulator for computer networking, pilot its use on students, and develop expertise in the use of simulation as an assessment tool applicable to other parts of the University. To meet the third aim, the paper starts with an extended introduction of simulator-based assessment and computer-based simulation. It then discusses the term "Virtual Assessment Environment". It introduces the simulator that has been developed, and discusses some of the issues that were faced during implementation. Finally, it presents a qualitative evaluation of students' views of how this could be used in the course. The conclusion is that students recognise many benefits of the simulator for formative assessment, but raise concerns regarding its summative use.

Overview of Simulator-Based Assessment

Simulation, when used as a learning tool, has the potential to allow students to learn about concepts that are too large, expensive, complex or dangerous to do for real. It may allow legal or ethical objections to be overcome. For example, civil engineers may learn how to build bridges using a simulator, because it would be expensive and dangerous to have them build a real bridge. First-aiders learn about resuscitation using a "Resusci-Annie" doll because of the dangers of attempting the procedure on a real patient. Lawyers learn about cross-examination in a simulated courtroom, because of ethical problems with cross-examining a real witness in a real case. Even computer games such as SimCity may offer potential educational benefits if used in an appropriate way.

These examples show three different types of simulation:

- a simulated bridge-building exercise may use miniature real-world components to construct a miniature bridge that can be tested by performing real-world tasks to it (for example pushing a model car over it);
- a simulated resuscitation uses custom-made equipment that is designed to provide feedback rather than realism; and
- a simulated court case uses role-play, with actors (or, more likely, fellow students) acting out a scenario chosen by the tutor (presumably chosen to stimulate discussion or reflection about a particular problem).

If it is possible to use various types of simulation as a learning and teaching tool, it is clear that they can also be considered as a summative assessment tool if a tutor observes a student using the simulation. Marks can be awarded for a student civil engineer's simulated bridge, or for a student lawyer's participation in a simulated debate. A "first-aider certificate" would be awarded if a student could manipulate the simulated patient in an approved way. Of course, some of this assessment may be time-consuming.

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In my opinion, the use of simulation as a formative assessment tool raises issues of efficiency including staffing (the resuscitation simulation may be meaningless unless there is feedback available about whether the student's approach is good or bad) and equipment (the bridge-building simulation would require equipment that would be difficult to provide on demand to a large class).

To summarise, while these simulations allow the tutor and student to interact in quite complex and creative ways, there remains the problem of scale. As class sizes grow, the required support demands more time from tutors, more equipment or both.

Computer-based simulation offers an alternative that, I believe, solves some of the problems of traditional simulation (while introducing new issues of its own). Depending on the nature of the simulated task, computer-based simulation may complement traditional simulation, or it may provide an alternative. Part of the role of *teacher as pedagogue* is to recognise this.

A computer-based simulation provides a custom-made computer program that allows students and tutors to interact with the simulation by manipulating objects and commands on the computer screen. For example:

- a computer-simulated bridge building exercise might allow the student to assemble components to make a bridge (for example “put some steel-reinforced-concrete here and some rivets here”), and will include an engineering model to estimate how the bridge will perform under certain conditions. It can allow a much wider range of components than a traditional simulation and can be tested under a wider range of scenarios (for example a lightning strike).
- a computer-simulated resuscitation might allow the student to manipulate the patient in a variety of ways (for example “tilt head, apply 5 breaths, apply 5 heart massages to top of breastbone”), and will include a physiological model to estimate how the manipulations have affected the patient's condition. It can allow much more manipulation than a Resusci-Annie and can give the user feedback for what they have done wrong as well as what they have done right. It can provide an environment where it is possible to practice skills that are rarely used.
- a computer-simulated court case might create a computer-mediated dialogue with the student, perhaps based on real court cases but including a model of human verbal interaction. This may seem far-fetched, but the research area dates from ELIZA (Weizenbaum 1966) to the present day (Loebner 2003). Because of the unpredictability of human verbal interaction, and the inevitable shortcomings in any model, I believe such a simulator is likely to be a less useful learning tool than a traditional role-play.

When used as a learning tool, a computer-based simulator would alleviate some resourcing problems. Rather than providing equipment to each student, all that would be needed would be a computer (and some resources to teach students how to use it). In a modern university, central IT provision means students have reasonable access to computers (and incentives to learn to use them for research, writing and communication).

When used as a summative assessment tool, to generate evidence for calculating marks, a computer-based simulator can use observation in the same way as a traditional simulator.

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One potentially significant difference is that assessment tasks can be set that allow students to experiment with the underlying models as well as to manipulate them. Another advantage is that the computer-based simulator can keep a transcript of the student's interaction, which may allow the assessment of a task to be separated from the task itself. This may provide some help with resourcing problems.

When used as a formative assessment tool, to generate learning feedback, a computer-based simulator can offer some useful "intrinsic feedback" (Laurillard 2002) to students without teacher involvement. For example "is the bridge still standing?" or "is the patient still alive?". With a "what happens next?" type of question, the student can decide their answer and then perform the simulation to see if they are right. Parush *et al* (2002) evaluate how learning can be improved if a simulator can record a "learning history" (their term for a transcript) to allow the student to review their own performance and restart the simulation from any point. Even in the courtroom example, where intrinsic feedback is harder to give, a simulated dialogue gives the student experiences that they can reflect on. I find the general approach compatible with Kolb's (1984) model of experiential learning. In addition, because students can give themselves formative feedback when they want, this may provide some help with resourcing problems.

Many examples of the use of computer-based simulation for teaching are documented, for example by Race and McDowell (1996, p.32) and by Laurillard (2002, chapter 7). Its use for assessment is less well defined in the higher education literature. Brown and Knight (1994) list non-computer-based simulation as a means of assessment and Brown (1999) extends this list to mention (but not explore) computer-based simulation. Race (2001) does not include any form of simulation in an extensive list of assessment methods, and Freeman and Lewis (1998, ch13) do not mention simulation in a chapter on using computers for assessment. Habeshaw et al (1993, p.14) describes some applications of assessment via computer-based simulation, but does not consider the issues involved. Laurillard (2002) describes the availability of "intrinsic feedback" as formative, but does not consider summative use. These citations give me confidence that the general area is worth exploring, with much work still to be done.

A slightly different type of computer-*assisted* simulator that has been successfully used for assessment is "Baby Think It Over" (Realityworks 2004). This is a realistic life-size infant simulator designed to give teenagers experience of childcare, while automatically recording instances of predefined interactions (or the absence of them) for later formative feedback and, in one documented case, for summative assessment (South Coast Today 1996).

To summarise, I believe computer-based simulation provides a good constructivist learning tool that has potential for reducing assessment loads. The ultimate intention of my research is to demonstrate this in a pedagogy-driven way rather than a technology-driven way. I aim to derive a set of issues that a teacher must consider when selecting and adapting the use of simulation as an assessment tool.

This intention makes a number of assumptions. The following is an initial list that is likely to be extended and revised as work proceeds.

- That people (including, but not limited to, teachers and students) are willing to adopt and accept some form of computer assistance in the assessment of students. Computers are already accepted in the learning process - often, I believe, with

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little scrutiny and with many notable failures. But I suspect their use in assessment is likely to receive more scepticism due to concerns about equity, plagiarism and the input of professional bodies.

- That computer-based simulation can become an accepted form of computer assisted assessment (when compared to the low-cost alternatives such as multiple choice questions).
- That the pedagogical issues of simulation can be understood and addressed.

It has been noted by Cowan (2003) that simulation-based assessment combines the three elements of constructive alignment (Biggs 1999) into one environment.

A Virtual Assessment Environment

Rae and Taylor (2003) note that a Virtual Learning Environment intrinsically knows nothing of learning. A computer-based simulator similarly knows nothing of assessment. However, I believe a simulator can be designed with pedagogy in mind, for example by encouraging or forcing students to encounter the elements of Kolb's learning cycle. Young and Cafferty (2003) describe how the student's reflections, abstractions and experiments can be incorporated into the simulated world to provide experiences the SOLO taxonomy (Biggs 1999) can describe as "extended abstract", and how this can provide formative assessment and opportunities for summative assessment. I call this type of pedagogically-based simulator a "Virtual Assessment Environment".

To develop my ideas in this area, I have selected one of the modules I teach that I believe is amenable to the approach. The "Internetworking" module is taught to more than 150 2nd year BSc, FdSc and MSc Computer Science students to give theoretical and practical knowledge of how the Internet works. The practical learning outcome is, 'To set up, configure and troubleshoot a TCP/IP network'. This practical task is one that students are likely to meet on their industrial placements or after graduation. However, it is difficult to assess, formatively or summatively, being expensive in time and equipment. The simplest assessment would require four computers, three network switches and six cables per student, with thirty minutes to create and test a specified network configuration. It is impossible to prepare and assess two hundred students with the available time and resources, even for such an unrealistically simple scenario.

Students are currently set a compulsory examination question to design a specified (but simple) network on paper. As an assessment it lacks validity, it is not aligned to the practical learning outcome and it cannot assess "process". Students' performance is often poor, perhaps due to the non-aligned assessment.

I believe a computer-based simulation of the components used to construct computer networks would provide an alternative approach to teaching the students using real components that can provide more realistic teaching scenarios without requiring extra resources. With such a resource, students can control their own formative assessment, and can obtain unlimited formative assessment without use of lecturer time. There is also an opportunity for summative assessment, with improved validity of assessment including both "process" and "product".

Clearly, there are significant concerns regarding issues such as: the validity of assessing a simulated skill rather than a real skill; the realism required of the simulator; equality

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between students with differing computer skills or with special educational needs. Research is required to investigate these issues, and consider the unintended consequences that inevitably accompany an educational innovation.

Therefore I decided to develop and evaluate a simulator-based approach to the assessment of this module. The specific technical objectives of the simulator would be to allow the student to:

- invent a realistic problem;
- construct a computer network from standard components;
- test the network for correct functionality;
- obtain a means by which they can assess their own progress; and
- provide information to allow a task to be summatively assessed.

Methodology

In order to investigate further the issues concerned with simulator-based assessment, I sought funding to develop the simulator described above, and to evaluate it as part of an ongoing action research project summarised by the following diagram (based on Lewin's model (Elliott 1991)).

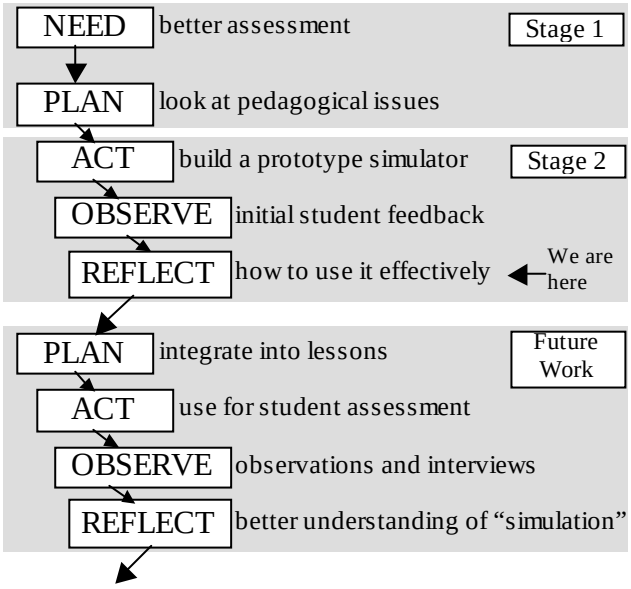

Figure 1 – The Action Research Spiral

The initial idea came from an assignment on the University's Postgraduate Certificate in Learning and Teaching in Higher Education. This led to a concept for what a simulator might look like, and Salford University funded a computer programmer to work over the summer to implement this simulator, leading to initial evaluation of students' perceptions of ways it might be used. The rest of the paper presents the results of this evaluation and reflection.

The evaluation was conducted in the following way (which was very much constrained by the time available to students within a busy semester):

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- the simulator was given to BSc Computer Science students to use as a revision aid, along with a demonstration of its use;
- some students were informally observed using the simulator;
- students were given a questionnaire asking for their views on the simulator. The questionnaire presented some ideas of how it might be used in future years and asked for their thoughts. The questionnaire was not intended to produce quantitative information, but to stimulate the process of reflection and planning.

Simulator Design Issues

This section describes the simulator, known as Netsim, that was developed to explore the issues relating to simulator-based teaching and assessment. Netsim has been developed to maintain as high a level of realism as is practical, while making the most of the advantages it has, as a simulated environment, to maintain the focus of learning rather than realism as an outcome. A consequence of this is that the following discussion has to assume some knowledge of the underlying technology.

An identified flaw of the existing laboratory sessions is that the students tend to learn the specifics of configuring a particular operating system, rather than the generic concepts involved. The procedures involved look very different on different computers, as the following figures show:

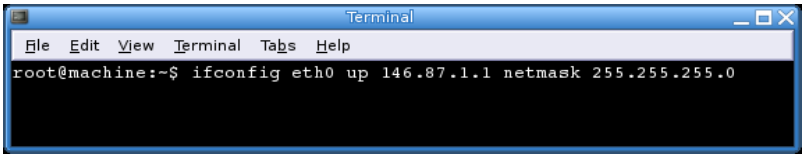

Figure 2 - A Sample Step of Configuring a Network on a Linux Computer

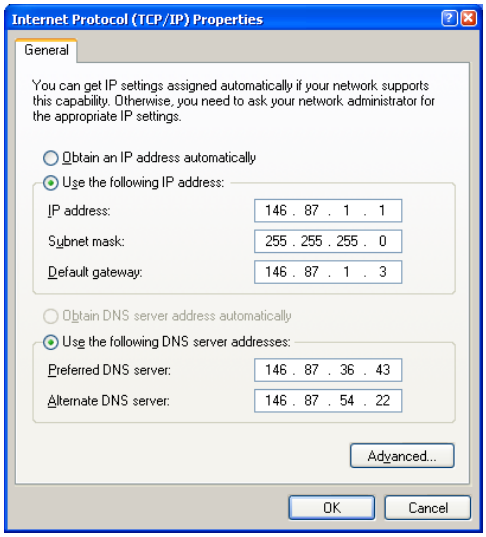

Figure 3 - A Sample Step of Configuring a Network on a Windows Computer

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Netsim aims to be platform-independent. Instead of teaching the individual commands that are specific to an operating system, it teaches the student the processes involved.

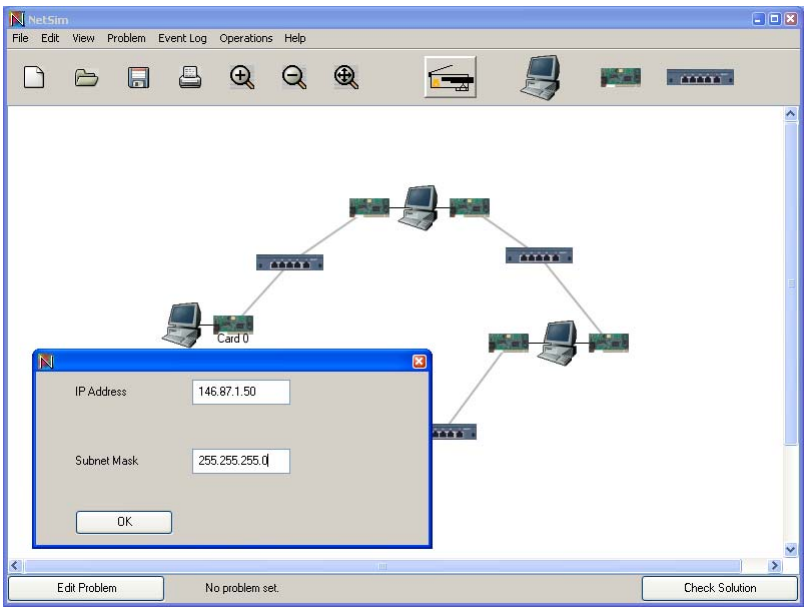

Figure 4 - A Sample Step of Configuring a Network using Netsim

Realism

Netsim tries to be as realistic as possible, to the extent that the user has to enable power on hubs, and to install the device drivers for a network card. However, some realism is sacrificed for ease of use and for learning objectives. The user does not have to log in on each machine to operate it, and the user obviously does not have to physically connect cables.

In reality, a network administrator can only prove that the network is correct by showing that every computer can communicate with every other computer. This is a laborious task, so one area where Netsim is unrealistic is that it automates this.

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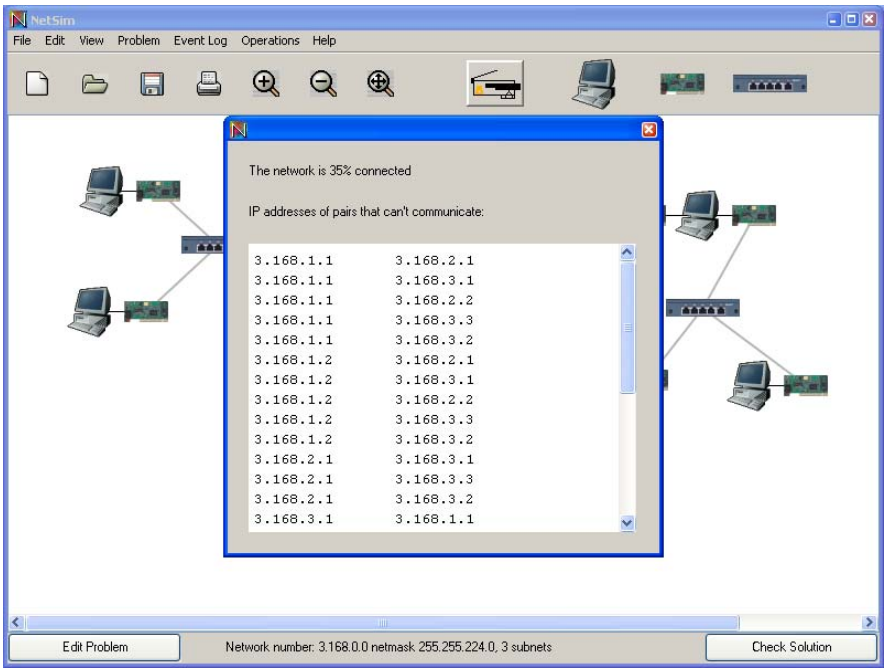

Figure 5 - Netsim Lists the Computers that can't Communicate with Each Other

Netsim also makes concessions for the tutor. In a laboratory-based examination, the student would set up a network, test it, then the tutor would test it to see whether it was fully connected and whether it solved the problem assigned to the student. Netsim allows the tutor and student to see at a glance how connected the network is, and how closely it matches the problem assigned. This provides the student with formative assessment, and it provides the tutor with summative assessment of "product".

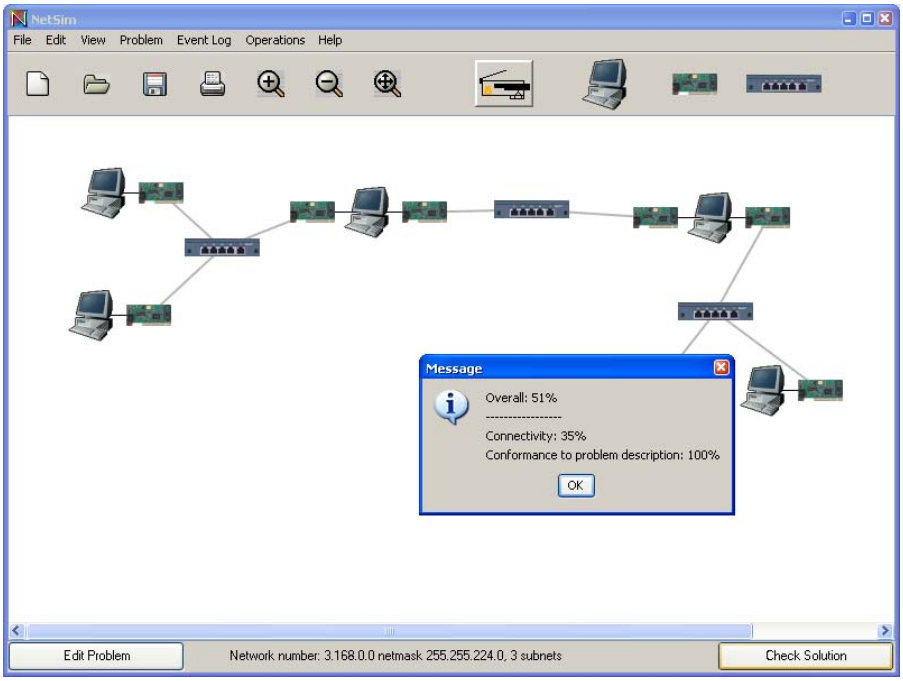

Figure 6 - Netsim Showing the Student's Progress

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Netsim provides an event log so that the tutor or assessor can see what steps the student took to get to their current position and provide feedback or assess "process". Real operating systems provide logs, but they are typically hard to locate and can be inaccurate or incomplete. This log also means that students can see their own events, which gives them added help in solving the problem, that can't be gained in a non-simulated environment - they can reflect on where they went wrong, rewind back to that point, and correct the mistake.

The possible disadvantage of this is that, when the student is performing the task for real, the student might expect to see a detailed event log like the one that Netsim provides. It is important to let the student know the differences between Netsim and reality, and this is a significant difference. Netsim is not only a simulator but a learning aid, and as such it sacrifices some realism for the goals of learning.

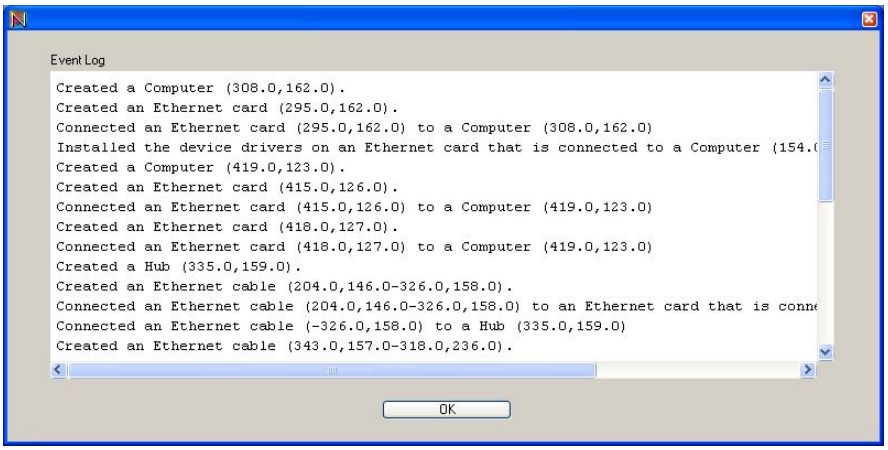

Figure 7 - Netsim's Event Log

Netsim has help files that go into the same level of detail as most reference books in network configuration (i.e., they cover the mechanics of setting an Internet address, but not the decisions and implications involved). The reason for Netsim to have help files is to make sure that the students can use Netsim independently of the tutor, and so that Netsim is self-contained, to allow people outside the degree course to understand its usage.

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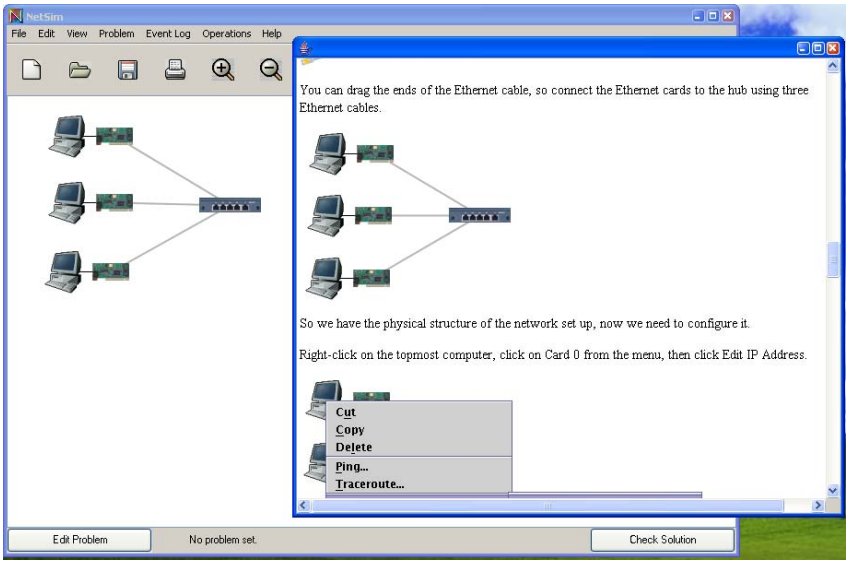

Figure 8 - Netsim's Help File

Implementation

Netsim simulates movement of data on the network, but it does not attempt to accurately simulate load levels, because the students are not learning about load management. It actually simulates one packet at a time, rather than having a realistic system where multiple packets can be processed at different parts of the network at the same time. This simplification makes writing the code a lot easier, which in turn means that the code is less error-prone. However, if the requirements of the project ever involve load management, some of the existing code will need rewriting.

Netsim allows the user a 'scrapbook' to enter their own notes about the network they are setting up. A real system administrator wouldn't have this functionality.

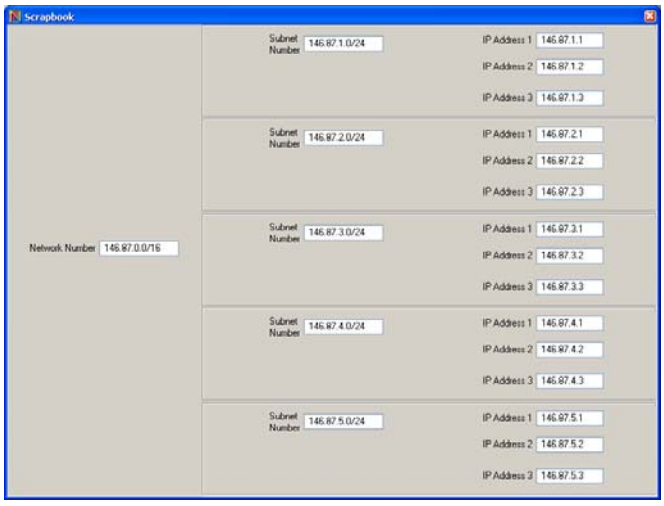

Figure 9 - Scrapbook for Entering Notes about the Network

For assessment, Netsim provides the functionality to download a problem from a remote site, and to upload the solution created later. This is more practical than physically

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evaluating the student's solution at the time, as the tutor doesn't have to worry about keeping the student's computer logged in while marking the work. This is implemented by having a remote web site with which Netsim interacts. The solutions are uploaded to the server, for the tutor to examine later.

Evaluation

124 second year students in 2003/4 were given Netsim half way through the second semester, and were asked at the end of the module for their views on how useful it had been and how they might use it. 50 of these responded, and I have used these responses to identify a range of views that can inform my future work. Informal observations had shown students using it methodically and regularly. Student responses showed around half had used it for some revision, but few had used it much. Time constraints and workload from other modules was cited as the main reason for this. However, students overwhelmingly planned to use it formatively as part of their exam revision.

Students complained that it was tedious to enable the power on each hub, and that it is difficult to see the Internet address that belongs to each computer. But these represent common real-world mistakes I have seen in classes. To see the Internet address on a real computer, you need to either click through settings or type a command; the computer itself doesn't have a label that shows the Internet address. In a real network, you need to plug in each hub, and check that its lights are on.

When asked how Netsim compared to the real tasks the students had been doing, student comments were:

+ “doesn’t rely on others”, “more time to experiment”, “quicker”
- “not physically done, which isn’t as good”, “can’t make real errors”, “uses more complex LANs”, “not comparable”

When asked how Netsim could be introduced into the module, student comments were:

+ “use for testing purposes”, “can build confidence for trying it practically”, “can do it at home”, “learn more by solving problems”
- “should have been introduced earlier”, “working practically and working on PCs is different”

When asked whether Netsim could replace the real tasks the students had been doing, student comments were:

+ “may be good idea to do both”, “continuous revision”
- “need to have hands-on experience” , “practical task is more real-world”, “important to manipulate real things in workshops”, “physically setting it up is more memorable”

When asked whether Netsim should be used for summative assessment, student comments were:

+ “will test practical knowledge”, “less tedious”, “can practice”
- “could be easier to cheat”, “prefer an exam”, “good to test people with time limits”, “useful for revision only”, “written test more of an advantage”, “practical exams are very bad”, “can do on paper easily enough”

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My interpretation of these diverse views is that students value the independence it would give, and can see potential benefits for formative assessment. But they are concerned about three things:

- the need to learn real practical skills rather than simulated skills;
- use of the simulator for summative assessment; and
- the time needed to learn to use the simulator.

The first issue is interesting, as the students are aware the "real" skills they are learning are extremely simplified to fit in with available resources, yet it is still seen as preferable to a simulation of a realistic problem. The students suggest that both should be done, and the time implications of this need to be considered.

I believe the second issue shows students' resistance to change (Ellsworth 2000). Even though the proposed assessment offers increased practice and flexibility, students feel comfortable with exams and have learnt to manage them. Innovation brings uncertainly, which a strategic student may not like.

The third issue matches with my own experiences. I had intended to have a more detailed trial with Foundation Degree students - a smaller group whose course had a highly practical emphasis. I had hoped to complement an 'observed practical test' with an 'observed simulation'. However, the plan was abandoned, as it was clear the student learning curve had not been properly considered. This would have led to a potential lack of equity and validity, with students being assessed in their ability to use the simulator rather than to understand the simulated task.

Conclusion and Future Work

I have described a project to investigate issues surrounding computer-assisted simulation. I have developed and described a simulator and have reflectively analysed my initial experiences using this with students.

The simulator has been well received by students, and I have gained a lot of experience that will help me to use it more effectively in the future. Although the simulator was designed to increase constructive alignment, the way it was introduced had paid insufficient attention to the teaching activities. I believe the simulator must be integrated into the teaching activities from day one, rather than being seen as a complement, in order to achieve its potential of improving the quality of teaching and assessment. This is consistent with Cowan's (2003) view that true alignment blurs the boundaries between teaching, assessment and learning outcomes rather than just requiring them to be compatible.

To take this work further, and particularly to examine generic transferable issues, I plan to undertake a qualitative interpretivist study of the way students use Netsim in 2005 based on observation, interview and event log analysis. To increase my understanding of the wider field of simulation, I hope to relate it to other areas of research such as Situated Learning, Structured Learning Events and Serious Play.

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