# RECENT EXPERIENCES AND DEVELOPMENTS IN THE TRAINING OF SIMULATIONISTS

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## ABSTRACT

As introduced in a paper in Building Simulation '93, the training of users of simulation based thermal performance assessment tools is central to the efficacy of such tools within professional practice. A will-structured training facility can act as a 'virtual laboratory' for researchers and students. It is now possible to report on the results of the evolution of a simulation environment (ESP-r), training support software and literature as well as a new set of observations of alternative approaches to training in academic settings, workshops and remote learning.

## INTRODUCTION

The inevitable evolution of simulation is towards observed complexity rather than away from it. For example, facilities for network based or CFD based mass flow predictions, building energy management functions, two and three dimensional conduction and the like are being included within thermal simulation. Thus underlying product models and demands for user interactions tend to become broader and deeper over time. It is crucial that the simulation community is able to deal with such complexity in ways which will encourage the uptake of simulation.

Two years ago, at a similar venue, it was stated [Hand 1993] that

*"... the efficacy of dynamic thermal performance simulation tools in the classroom, laboratory, design office or consulting practice is dependent not only on the facilities offered by the tools and the rigour of their underlying calculations but on the skills of the user vis-a-vis abstracting the essence of the problem into a product model, choosing appropriate boundary conditions, setting up simulations and interpreting their results."*

It was also suggested that an evolution was required, both to simulation tools and in the provision of training within universities and the professional community for simulation to be accepted as a tool within the design process. Further, such an evolution would be enhanced by feedback from students, simulation experts, project managers, consultants and those involved in simulation based technology transfer initiatives.

Subsequent work and observations at the University of Strathclyde has reinforced rather than refuted these ideas. Indeed, a holistic approach - where aspects of tool development, training and use in practice have jointly formed a platform for conjecture and testing - is, we believe, more robust than approaches which rely on isolated evolution.

## AN ACADEMIC FOUNDATION

In order to influence the interests and skills of the design and engineering professions one might begin by expanding the place of simulation within the curricula of professional degrees. Within the Energy Systems Division of the University of Strathclyde, simulation has been associated with doctoral level work ever since the mid 1970's. It has been an elective topic at the post-graduate level for several years. Recently, the University has become one of the few institutions offering simulation within undergraduate degrees - first to 4th years, and currently to 3rd and 4th year students in Environmental Engineering and Building Design Engineering degrees. It is planned to continue this process until aspects of modelling and simulation are included even within the coursework of first year students.

This aim is related to the three premises underlying the Environmental Engineering course (Clarke et al. 1994): (1) that an understanding of fundamental engineering principles is vital and will lead to more creative and applicable design solutions, (2) that industry relevant, team-based design projects will engender an appreciation of the issues and limitations relating to best practice, and (3) that skills in the application of IT and computer modelling will allow the effective appraisal of options at the design stage.

The goal of progressively introducing simulation to users earlier in their studies has been a fertile testing ground for interfaces, teaching materials and instructional techniques. Each subsequent introduction has brought into focus aspects of simulation which have been taken for granted or which have illustrated gaps in foundation coursework and topics which require to be made prerequisites to a course in simulation.

This has required a relaxation of the traditional demand of simulation tools that the user be well versed in the disciplines of heat and mass transfer, environmental control systems and the like. This has required a re-appraisal of the flow of information between the user and the tool and the degree to which a simulation session can be constrained to deal with a specified topic while not encroaching on the mature users ability to 'drive' the simulation tool. The implementation of this has revolved around the existence of *interfaces with clarity and consistency*, access to a range of *exemplars*, *tutorials* and *training* options.

## INTERFACE CLARITY

Traditionally, simulation tools have required the user to focus a great deal of attention on interactions with the tool. For some users this distraction has been observed to reduce their ability to devise appropriate abstractions of reality and simulation methodologies for the complex interactions within the built environment. This is changing and simulation environments are currently evolving in ways which allow a user to focus more of their attention on simulation rather than interaction tasks. Although each has adopted different interface styles to work with their underlying product models and solution techniques, it is possible to see such interface evolution within the IFe[Clarke and Mac Randal 1993], in ESP-r[Hand 1994], the soon to be released PowerDOE[Crawley 1995] and the new interface modules of TRNSYS.

We have observed that an interface to the product model and facilities of a simulation environment can be robust with the following essential characteristics:

a) The degree to which it provides multiple streams of feedback. A combination of images and attributed entities (see Figure 1) appears to be particularly powerful. We have noted a positive response from the majority of users carrying out various simulation tasks as descriptive entities have come to be increasingly treated (and presented) as objects in which all associated attributes are available for inspection and editing.

b) Clarity and consistency. This has little to do with a fashionable interface and everything to do with WHAT is being presented and how the product model is expressed and maintained in a consistent state. For instance, reporting which is understandable by various user types, the uniform provision of reasonable defaults and contextual help for all user interactions as well as a reliable decoding of internal data constructs into an unambiguous external form.

The above can be achieved without resort to buttons, 3D forms, extensive use of colour, proportional fonts or icons. This is not to say that such interface devices do not have a place in simulation, rather that they benefit from a solid foundation.

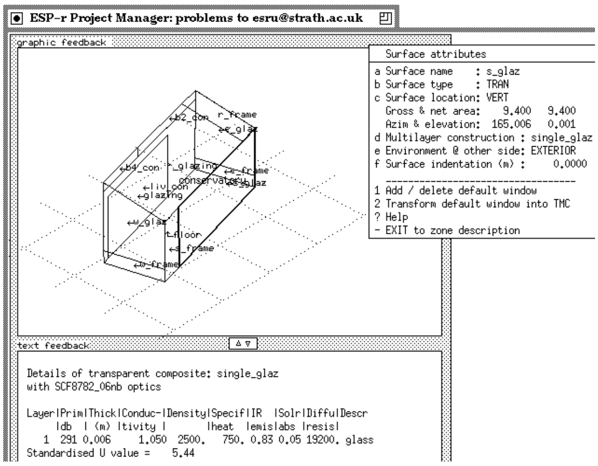


Figure 1: Multiple feedback streams.

It has been found that clarity and consistency are essential attributes of a simulation environment. It is important that all aspects of simulation practice from interface elements, underlying product model, quality control, reporting and simulation facilities are viewed in this light. Inevitably, it is instances which depart from this which cause confusion or which break the concentration of the user.

Workshops have been useful venues for discovering points where confusion begins to manifest itself. It has been possible to alter elements of the interface, tutorial materials or instructional techniques separately or in combination to see if this reduces confusion. Interestingly, there have been few cases where a change which increases clarity for one class of user has been detrimental to others.

## ACCESS TO EXEMPLARS

It was proposed [Hand 1993] that distributors of simulation tools move from ‘toy’ problems to fully documented and attributed exemplars of simulation projects which span the range of problem types and assessment tasks associated with such simulation environments. It is now possible to assess the impact of such a change.

A mechanism has been enabled to allow access to remotely held simulation problems to assist in teaching, distribution of work within dispersed simulation programmes, as well as potentially allowing managers to provide selective access to their firms’ past and current simulation projects. As long as the descriptions of such projects are self consistent, attributed and documented there is no particular limitation (other than disk space) to the number of projects in a collection or the number of collections which might be composed.

It has been possible to choose simulation projects which are exemplars of particular facets of simulation or of best practice approaches to simulation tasks. Figure 2 shows a selection list which has been set up for a 4th year environmental engineering course. Items at the top are appropriate for a novice (graduated introduction of descriptive entities and simulation complexity such as the addition of viewfactor and insolation analysis) while those at the bottom of the list would be more appropriate for cross-disciplinary studies of HVAC systems in an office building.

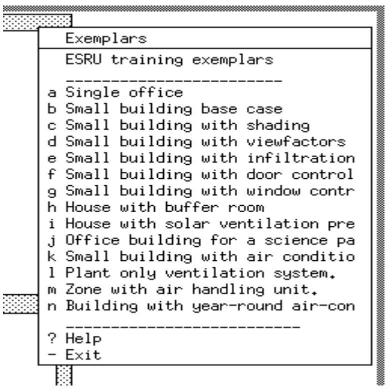


Figure 2: Exemplar selection list.

The user may browse an exemplar in order to understand its composition and explore its performance by running one or more simulations. This presumes no particular knowledge of either the simulation environment or the simulation problem and usually does not require the user to supply information from the keyboard - only make mouse based selections. Alternatively the user can ask for a copy of the exemplar to be placed in their own directory structure after which they can undertake any degree of modification appropriate to their work. Exemplars of greater complexity have been especially instructive to users of intermediate skills who wish to understand the composition of simulation problems appropriate to the complexity found in "real" design problems.

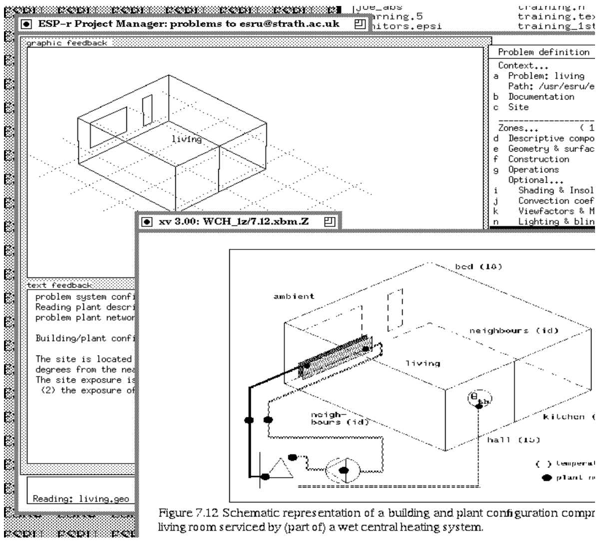


Figure 3: Browsing an exemplar.

## TUTORIALS

In addition to the ability to select, browse and acquire exemplars, users have access to an on-line tutorial facility (Figure 4) which covers each of the application modules, the simulation product model, associated databases, exemplars and a glossary of terms. Being fully extensible and not constrained to the English language, it has been possible to update the on-line facility to keep pace with the evolution of the simulation facilities and to allow printed users manuals to become a secondary resource. As opposed to contextual help within an application, a tutorial facility makes it possible to extend the depth and detail of topics so that complex issues such as aspects of simulation methodology can be introduced.

It has been observed that such facilities have reduced the degree to which new users have had to rely on access to experts to answer the more mundane aspects of simulation practice. Where it has been possible to enforce a training regime wherein users access an on-line tutorial before attempting simulation tasks our observations have shown an improved comprehension of the simulation environment, and more efficient use of tutors’ time.

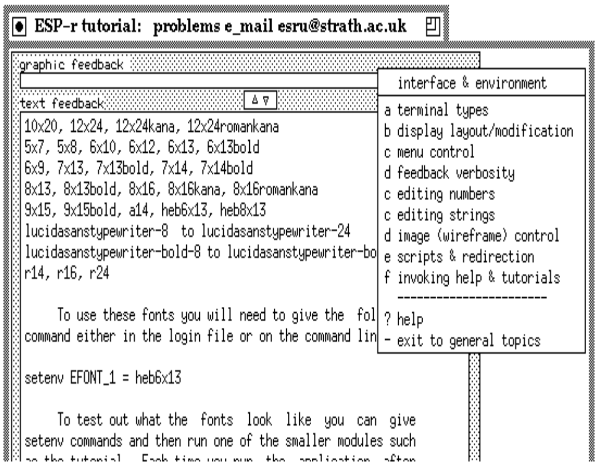


Figure 4: On-line tutorial facility.

Experience has also highlighted a number of limitations in the on-line tutorial. The search engine is not hypertext based, so cross links are more difficult to implement. A text based tutorial makes the presentation of certain topics problematic. Feedback from users has also raised questions as to the topics to be covered by the tutorial which are independent of the interface. Some students have complained, for example, that the results analysis module includes a comfort reporting facility which requires "Clo" values, metabolic rates and the like as input while the tutorial provides only a minimal background on such terminology. The question arises as to the level of competence demanded of a user of the system and whether an attempt to comply with such demands will obscure essential information required by mature users.

Currently the on-line tutorial, in conjunction with the exemplars and teaching materials are being extended in the direction of assisting mature users to use the simulation facilities and descriptive syntax to achieve particular assessment aims. for instance, a discussion of steps to increase the robustness in a project focused on temporal patterns of radiation and notes on control schemes and reporting facilities which would support a study on the influence of ventilation on comfort. Certainly there are topics such as fuzzy logic control systems which only an expert would attempt and such tutorials would be specific to that class of user.

To explore an alternative form of tutorial ESRU has recently published a hypertext tutorial (see Figure 5) on the World Wide Web: (http://www/strath.ac.uk/Departments/ESRU/tutorial/tut_start.html). Starting from the contents of the on-line tutorial, images, links and additional topics have been added. Figure 6 shows an explanation of editing facilities. This level

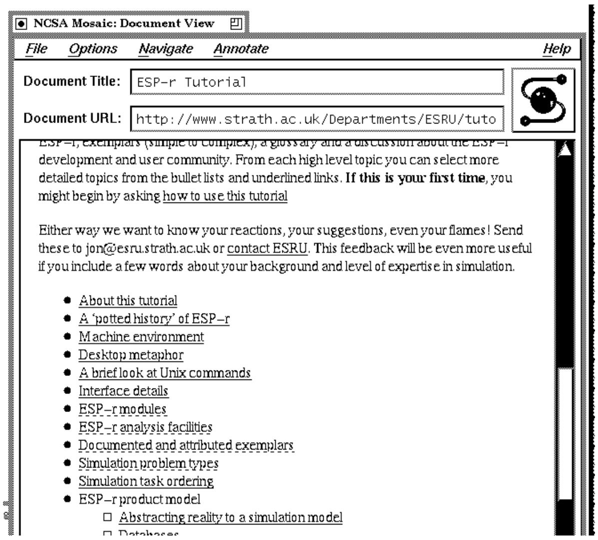


Figure 5: Hypertext tutorial facility.

of assistance is useful, but hardly ground breaking. Where it becomes interesting is where explanations of methodology have been introduced as in Figure 7 and in specific support of remote users.

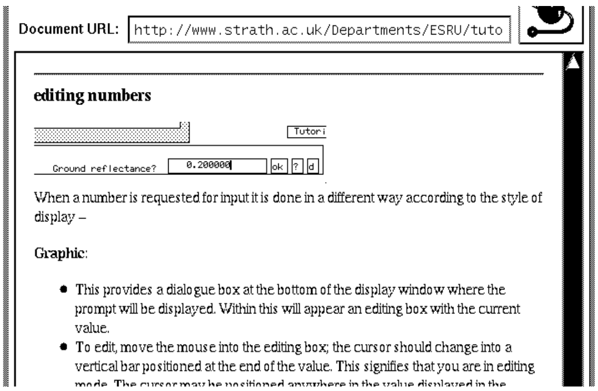


Figure 6: Text and image guide to interface training.

Feedback thus far has indicated that its use is more intuitive and that some of the topics are more understandable. Certainly there is little of the control and selection logic which cannot be expressed via Hyper Text Markup Language and it would appear that considerable latitude exists as to the breadth and depth of topics which could be maintained. The inclusion of images has not slowed access to most remote users as monochrome bitmaps have usually been adequate and all large images have been expressed as optional links.

Another benefit of a WWW implementation is that those who have not yet acquired the system or do not yet have access to workstations can appraise aspects

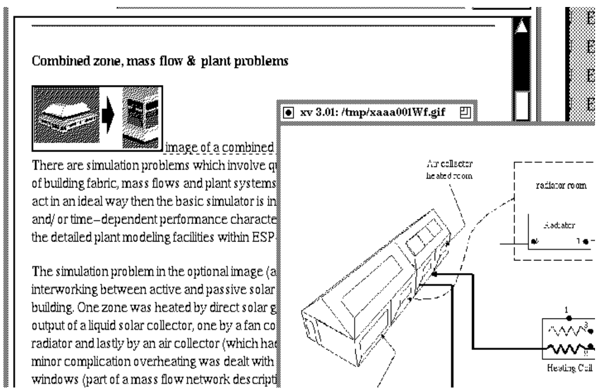


Figure 7: Hypertext introduction to methodology.

of its interface, product model and functionality before proceeding further. A number of Universities have links to the tutorial for use as an introduction to the possibilities of simulation. As a mechanism for the support of remote learning such a facility has many benefits and these will be discussed in a subsequent section.

## TRAINING

We have observed that teaching keyboard skills, operating system skills and the navigation of a simulation environment has become less problematic. Tools that are consistent in their interface elements, provide multiple streams of feedback and offer contextual help and sensible defaults have allowed training efforts to be directed to higher level issues. In comparison with how naive and mature users came to grips with a new simulation environment five years ago the process is much improved.

Surely then the introduction of ever more intuitive interfaces, exemplars and tutorials has put paid to the demand that a successful simulationist must be an expert (typical backgrounds would be building physicists, environmental/mechanical engineers or academics). The answer, based on observations, is that most users progress with greater rapidity but rarely in a *different direction* than they otherwise would have:

- experts benefit by being able to concentrate on their simulation goals and possibly to be able to approach their tasks more explicitly,
- the novice attains keyboard skills more quickly and feels able to attempt a level of compositional complexity which occasionally outstrips their skills in other aspects of simulation,
- those who have a tendency to view a robust simulation as one in which all available options are used have fewer technical constraints between them and the complexity to which they inevitably arrive.

We have observed that proficiency in the operational aspects of simulation does *not necessarily equate* to being a simulation expert. Training in simulation methodology and abstraction of the simulation problem are still required.

Experience thus far is that the time required to reach the point where the user is capable of undertaking the planning, composing and execution of a multi-zone simulation problem with subsequent analysis will range from a day or two for a professional with prior experience in simulation to about 5 full days (over a 10 week semester with weekly tutorials/labs) for a third year student with no workstation experience.

It is the expert or prior user of simulation who continues to benefit the most from the evolution of interfaces and the introduction of exemplars, tutorials and productivity aids. It is especially interesting to note that such users inevitably devote the initial period of their training in discovering how the physical process such as radiation, convection, mass flow or control systems which form the general domain of their work are represented and treated within the new simulation environment. With access to an expert to respond to specific questions, they rapidly move up the learning curve to perform non-trivial simulation problems.

This has not been the case with students, who - although much less than in the past - rely on help by tutors because of:

- their lack of domain knowledge,
- their underdeveloped problem solving skills and strategies,
- discrepancies between their view of the product model and that of the program developer.

In general the students seem to have more problems with aspects like model definition and simulation methodology than with the actual simulation and analysis of the results. It should, however, also be mentioned that the majority of students are very well motivated. Their willingness to actively learn increases considerably when the problems to be simulated are generated by themselves (perhaps originating from other design classes).

Especially in the case of students, it was observed that an initial series of structured exercises which become progressively complex works very well. However it was also observed that students only absorb the learning experience when these exercises are accompanied by a series of assignments which need to be submitted and marked. In our case the students have to send the assignment results and their course reports by electronic mail which has the side effect that their proficiency of using the technology increases considerably.

We have observed a tendency for novices to attempt complex simulation models before they are capable of addressing such complexity or recognizing when such complexity is warranted. The advent of user-friendly interfaces has been observed to accentuate this problem rather than reduce it. It is not uncommon for groups who are beginning to use simulation to post email queries about how to represent structural connections or 3D aspects of ground heat transfer. That such descriptive complexity might not be warranted in an assessment of their design or that there is no data on sub-soil composition or temperature regimes at a site tends to be illuminated in subsequent correspondence.

The idea that simulation based projects fail because managers have difficulty in accessing and evaluating the work of their staff is not much discussed in the simulation community. The causal factors are numerous and include, among other things, simulation software which is "opaque" to management, traditional assumptions about simulation based programmes of work and flow of information, and the absence of managers from simulation training regimes.

The introduction of "project management" facilities to the ESP-r system and the ability to browse simulation problems was initially a response to observations of project managers and those who required intermittent access to simulation based descriptive and analysis data. The point has been reached where knowledge of one file name and the ability to select menu options is the prerequisite for browsing all levels of the description of the problem. Similarly, one file name will suffice to gain access to the results of a simulation. What remains is to convince managers of simulation based programmes to make use of such facilities.

Increasingly, training regimes have been altered to address the needs of project managers. Typically managers have taken part in initial discussions and demonstrations of the simulation environment, use of tutorials, access to exemplars, nature of simulation results and the like. Depending on the organisation, managers and staff have also worked with tutors on issues of project planning, quality assurance, information extraction, setting up of corporate databases, project directories and access to current simulation work. It has not yet possible to make a conclusion regarding the degree to which management training has resulted in the more effective use of simulation.

## THE CONTINUING CHALLENGE

The real challenge appears to be in dealing with issues of simulation methodology, project management and devising appropriate abstractions of reality. It is hard to imagine an evolution in interface sufficient to release the user of this burden. The resource necessary to expand the breadth and depth of tutorials has thus far limited the treatment of such topics. However, the advent of WWW based facilities would appear to open up a number of possibilities for addressing such issues.

Exemplars have been a step in the right direction. Their current embodiment allows users to explore much of the essential descriptive syntax, relationships and facilities within simulation. Subtle assumptions and judgments have been difficult to convey. Even a well documented exemplar requires a non-trivial investment in exploration by the user (and some idea of what to look for). While this is not an unreasonable demand it has been observed that exemplars work better in a workshop setting where experts are available than in remote/ independent sites. It may be that as the tutorials become more closely matched with exemplars that remote users will be less disadvantaged while those in workshops will be able to make better use of their tutors’ time.

The prior observation that "paper, pencils and planning" were core aspects of simulation has, if anything, been observed to be of greater importance as users have been liberated from some of the mundane aspects of composing their problems. Ease of use and the ability to evolve simulation descriptions in an ad-hoc way do not absolve the user from careful consideration of how simulation problems are composed and how they will be used. It falls then to the user to ensure such aspects of simulation are accounted for and only well trained users are in a position to know how to approach such tasks and the care and attention required.

In earlier work, ESRU explored the use of bespoke interfaces for specific user types [Clarke and Mac Randal 1993]. This has typically been beyond the resources of most development teams [Hand 1993] if not premature, as basic issues of clarity had not been dealt with. Perhaps it is now time to contemplate steps in the direction of bespoke interfaces. There are, for example, some of the more complex simulation facilities which could be made more difficult for undergraduate students to access. There are optional facilities such as the calculation of viewfactors and temporal shading patterns which might be prerequisites for certain classes of assessment.

Rather than attempting to expand current application code, such bespoke facilities might well be prototyped and explored within the context of an Intelligent Integrated Building Design System (IIBDS) which has been the focus of the EU COMBINE II programme [Clarke 1994b]. Within an IIBDS, knowledge is used to control not only the interactions between tools in the design process but the behaviour of the tools and the nature of the information presented.

Even if conventional tutorials and simulation interfaces do make some concessions to differing levels of proficiency, they are deficient in mechanisms to detect and act on the progress (or lack of progress) of the user. Even the best tutor has limits as to the degree of attention which can be directed at observing a single user, let alone how the participants in a workshop approach simulation tasks and the paths they follow within a simulation environment. Yet such observations are precisely the feedback which will ensure that simulation environments and the support given to the user community are increasingly appropriate. What is required is an environment which captures a journal of the interactions between the user and the tool and a knowledge based agent to infer from this a users progress. This is where current research into journaling [Clarke 1994b] is focused. A portion of a design session under knowledge based control and the resulting journal are shown in Figure 8. Such a mechanism allows researchers to capture and understand how the interactions typical of direct access to an expert and a directed training regime can be expressed.

## SUPPORT FOR REMOTE USERS AND DEVELOPERS

If an optimal training regime includes access to an expert tutor as the user works on a series of progressively more complex projects, how then is it possible for a remote user of a simulation environment to become proficient? This question grows more relevant as it becomes easier for developers to install and maintain software at remote sites.

As simulation begins to be taken up within universities there are infrastructure issues which require to be dealt with. To this end, ESRU has recently made a proposal in the context of the EU TEMPUS programme (Trans-European cooperation scheme for higher education) with the objective of introducing IT based environmental simulation courses in central and eastern European universities.

Certainly electronic mail and file transfer has proved to be crucial to distance learning, cooperative development work and communication within the user community. Indeed, hitherto tedious and resource intensive tasks such as the exchange of simulation models for comment and debugging is beginning to be routine. This said, there are limitations in such approaches, particularly when dealing with issues which do not fall into the category of frequently asked questions.

We are thus exploring an alternative of re-casting the tutorial facility and some distance support tasks within the framework of World Wide Web browsers. The implications of this are far-reaching - not only can users have a richer tutorial environment, archives of frequently asked questions, images and discussions are possible. It looks possible to represent the inherent interconnections between thermophysical processes as well as simulation facilities via hypertext links. Certainly the computer aided learning community is considering the WWW as a teaching medium [Parrington 1994].

## CONCLUSIONS

The training of users of simulation based thermal performance analysis tools has been cited as crucial to the efficacy of dynamic thermal simulation tools within professional practice and for its use as a 'virtual laboratory' for researchers and students. The authors have reported on the evolution of a simulation environment, training support software and literature as well as a new set of observations of alternative approaches to training in academic settings, workshops and remote learning. The major findings of the current study are:

- Simulation has been successfully introduced into the undergraduate curricula of Environmental Engineering and Building Design Engineering courses.
- It has been found that clarity and consistency are essential attributes of a simulation interface.
- Tutorials have been introduced both as on-line and World Wide Web browser based facilities and appear to address many of the needs of both novice and expert users.

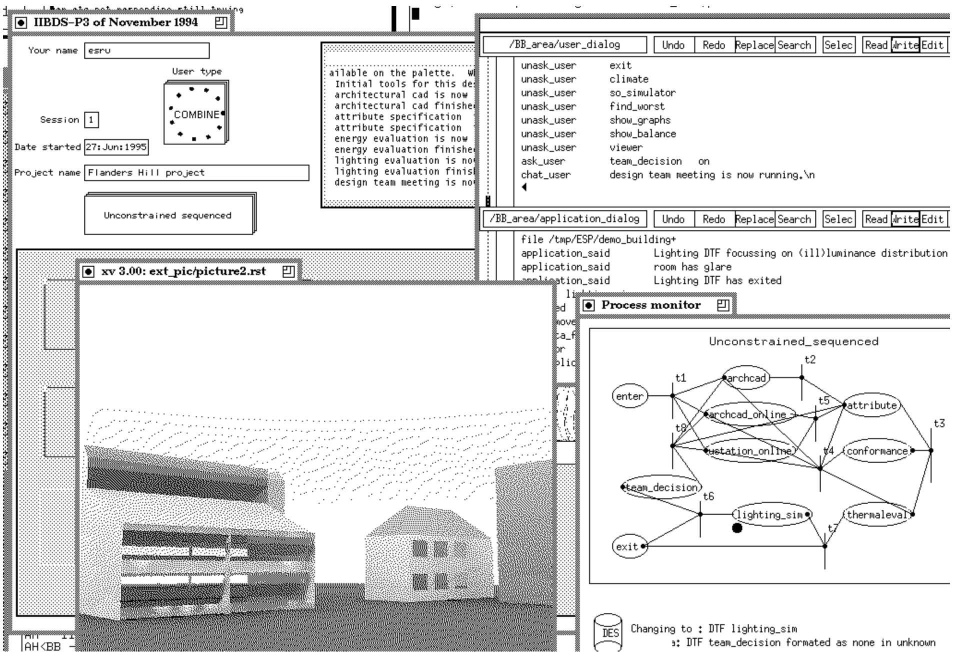


Figure 8: Journaling within an IIBDS.

- Routine access to a range of simulation exemplars has been proven to be an aid to academic instruction and simulation workshops. The underlying mechanism has also been seen to be of benefit to professional firms and as a means for sharing simulation models between geographically dispersed groups of users.
- Although recently introduced, there are grounds for optimism that the needs of simulation project managers and a range of user types are beginning to be addressed.

The simulation community is thus in a position to reduce the frequency of users attempting assessment tasks for which they are unprepared, untrained or which are inappropriate for the tool they are using. Still to be resolved are mechanisms to assist users to resolve methodology and abstraction issues before complex assessments are attempted.

It is time for the simulation community to redouble its efforts to increase the competence of its existing user community, perhaps via courses of continuing professional development, and to find ways to influence those about to enter the design and engineering professions. This will not only result in clients being better served, but in a user community which makes better use of its resources.

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