Hand, J.W. & Hensen, J.L.M. (1995).
Recent experiences and developments in training of simulationists.
Proceedings of the 4th IBPSA World Congress "Building Simulation '95", August, pp. 346-353.
Madison: International Building Performance Simulation Association.

Recent Experiences and Developments in the Training of Simulationists

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ABSTRACT

As introduced in a paper in Building Simulation 93, issues surrounding the training of users of simulation based thermal performance assessment tools are central to the efficacy of such tools within professional practice and 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 as to 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 the integration of network based or CFD based mass flow predictions, building energy management functions, two and three dimensional conduction and the like. Thus underlying product models and demands for user interactions tend to become richer over time. It is crucial that the simulation community be 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 rigor 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 required a balanced exposure to the naivete of students, the opinionated demands of simulation experts, the bemused detachment of project managers as well as facilities to meet the demands of consulting and simulation based technology transfer programmes.

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 it has long been the goal of the academic community to introduce simulation into their curricula. Within 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 here-to-for 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.

What has been required is to relax the traditional demand that the user be well versed in the arcane 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 *ubiquitous interfaces*, access to a range of *exemplars*, *tutorials* and *training* options.

THE UBIQUITOUS INTERFACE

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 reduced their ability to devise appropriate abstractions of reality and simulation methodologies to assist in understanding complex interactions within the built environment. This is changing and simulation environments are currently evolving towards releasing the users attention even as their complexity grows. 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, 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 rich product model and facilities of a simulation environment can be robust with the following essential characteristics:

a) The degree to which it provides redundant feedback. A combination of images and attributed entities (see Figure 1) appears to be particularly powerful. We have noted a positive response for the majority of users carrying out various simulation tasks as descriptive entities have come to be increasingly treated (and presented) as objects wherein 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, 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 terse data constructs into an unambiguous form.

The above can be achieved without resort to radio buttons, 3D forms, extensive use of colour, proportional fonts or icons.

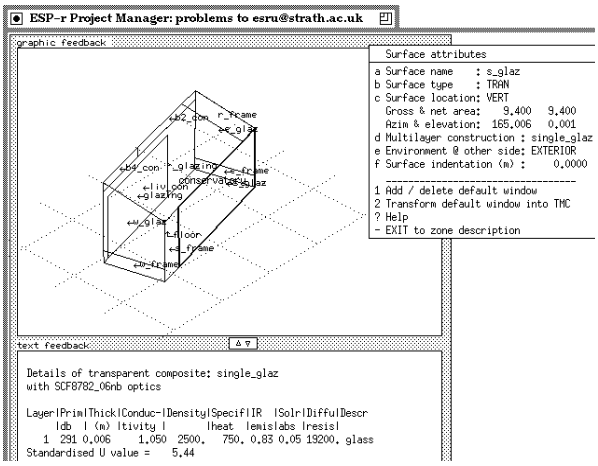

Figure 1: Redundant feedback.

It has been found that clarity and consistency are essential attributes of a learnable 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 during the period of a workshop 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 environments 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.

We have used a mechanism for allowing 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 then, 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 setup 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 temporal 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.

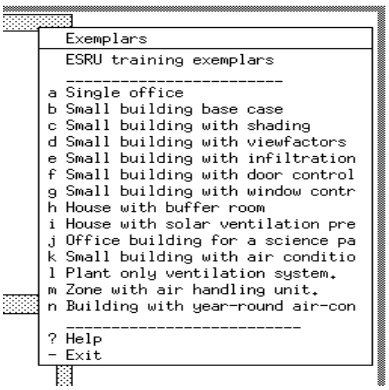

Figure 2: Exemplar selection list.

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 had 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 language independent 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.

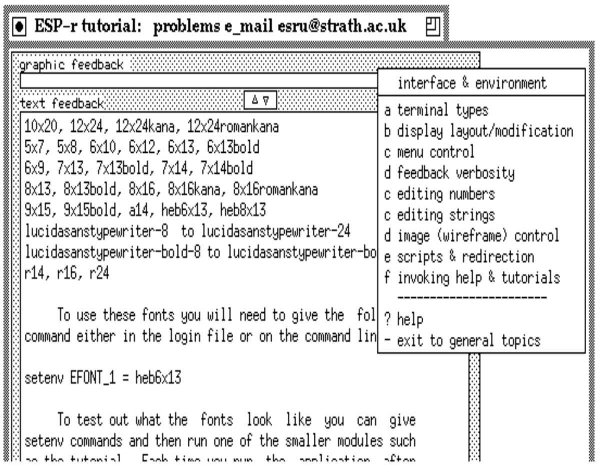

Figure 4: On-line tutorial facility.

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.

Experience has also hilighted a number of limitations in the on-line tutorial. The search engine is hierarchal rather than 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 as input "Clo" values, metabolic rates and the like 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 so obscure essential information required by mature users.

In reviewing the questions and responses of professional users our tendency would rather be to extend the tutorial in the direction of assisting users to use the simulation facilities and descriptive syntax to achieve particular assessment aims. For instance, if a design problem revolved around the assessment of temporal patterns of radiation distribution how would one setup the problem to make this as robust as possible. If one were interested in the influence of a ventilation on comfort what control schemes are available and which reporting facilities would support such an analysis. 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.

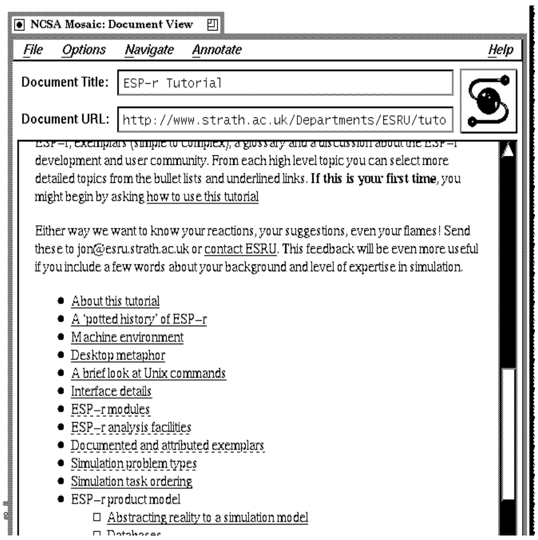

Figure 5: Hypertext tutorial facility.

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

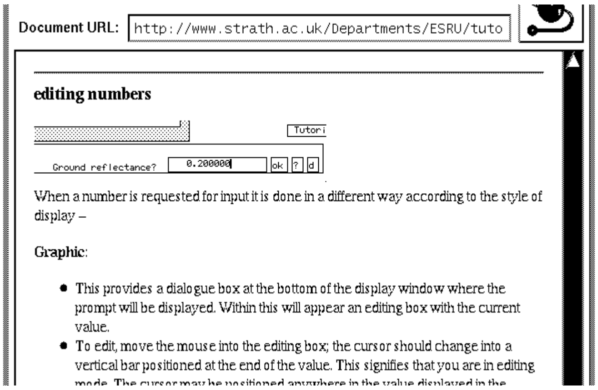

Figure 6: Text and image guide to interface training.

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 bespoke control and selection logic which cannot be expressed via HTML 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.

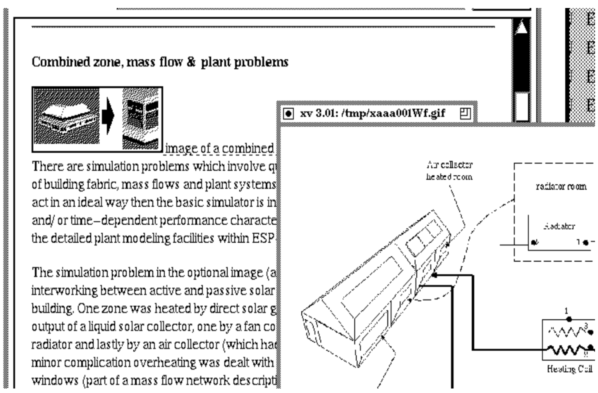

Figure 7: Hypertext introduction to methodology.

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 of its interface, product model and functionality before proceeding further. A number of Universities have links 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 straightforward issues of teaching keyboard skills, operating system skills and providing assistance in navigating through the often Byzantine hierarchy of a simulation environment have become less problematic. Tools that are consistent in their interface elements, provide a degree of feedback so that surface shapes, names, attributes and the like are seen to respond to users actions and offer contextual help and sensible defaults, tend to become ubiquitous, once such basic skills are acquired. 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 opinionated 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* then they otherwise would have:

- experts benefit by being able to concentrate on their simulation goals and possibly to be able to more explicitly approach their tasks,
- the novice will attain keyboard skills more quickly and feel able to attempt a level of compositional complexity which occasionally outstrips their capacity to bring to a successful conclusion,
- the tool-led-user has fewer technical constraints and certainly less reason to contemplate the stifling complexity to which they inevitably arrive.

Although the relaxation of learning curves reduces the resources required to attain expertise, we have observed that technical proficiency does *not necessarily equate* to expertise in the absence of training.

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 multizone 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 aides. 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 a 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,
- deficiencies in their understanding of the product model,
- their not yet developed problem solving skills and strategies,
- discrepancies between their view of the product model and that of the program developer, and
- sometimes their inability of continuous concentration.

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, we observed that an initial series of structured exercises which are progressively complex works very well. However we also observed that students only absorb the learning experience in case 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 attempt complex simulation models before they are capable of addressing such complexity or recognizing when such complexity is warranted. The advent of less hostile interfaces has been observed to excentuate 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 to stair treads or 3D aspects of ground heat transfer. That stairs might optimisticly form a fourth order affect in the 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 programmes fail because managers are unable or unwilling to access and evaluate 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, organisational patterns which limit management awareness, traditional assumptions about simulation based programmes of work 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 such observations. 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.

It has now been possible to undertake training regimes where 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 conclude 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 to addressing such issues.

Exemplars have been a step in the right direction, but are not yet rich enough to convey subtle assumptions and judgments. 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, Mac Randal 1993]. This has typically been beyond the resources of most development teams [Hand 1993] if not premature as basic issues of clarity and robustness had not been dealt with. Perhaps is is now time to contemplate steps in the direction of bespoke interfaces. There are, for example, simulation facilities which are clearly beyond the remit of most undergraduate students and which might ought to be hidden. There are optional facilities such as the calculation of viewfactors and temporal shading patterns which might ought to be prerequisites to a certain class of assessment.

Rather than attempting to expand current application code, such diverse facilities might well be prototpyed 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 behavour 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 this is precisely this type of 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 the 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 would allow researchers to capture and understand how the interactions typical of direct access to an expert and a directed training regime can be expressed.

Figure 8: Journaling within an IIBDS.

SUPPORT FOR REMOTE USERS AND DEVELOPERS

If an optimal training regime is to have access to an expert tutor and then work on a series of progressively more complex projects with that expert, 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.

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 beyond advise on compilation options and setting up control regimes.

We are thus exploring an alternative of re-casting the tutorial facility and some distance support tasks within the framework of the World Wide Web browser Mosaic. The implications of this are far-reaching - not only can users have a richer tutorial environment, an archive of frequently asked questions, images and discussions are possible. It looks possible to mirror 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]. As a matter of fact, ESRU has recently made a number of proposals in the context of the EC 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.

Another observation which, like the lack of integration of management into the simulation support design process, is of potential concern to the simulation development community, relates to remote users of simulation who do a disservice to the profession and their clients by attempting assessment tasks for which they are unprepaired, untrained or which are inappropriate for a particular simulation environment. Much of this could be mitigated by training, and by more frequent communication. It is apalling the resources some users will squander on a simulation exercise before they seek assistance and their reluctance to consult on methodology and abstraction issues before undertaking complex assessments. It may be time for the simulation community, perhaps via IBPSA, to consider certification of simulationists, certainly it is time for the simulation community to redouble its efforts to increase the competence of its existing community and to find ways to influence that of those about to enter the profession.

CONCLUSION

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 as to alternative approaches to training in academic settings, workshops and remote learning. In particular, it has been proposed that the simulation community continue to evolve training towards the needs of managers of simulation programmes and remote users.

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