The design and the formative evaluation of a web-based course for simulation analysis experiences

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Received 16 July 2001; accepted 18 November 2003

Abstract

Simulation output analysis has received little attention comparing to modeling and programming in real-world simulation applications. This is further evidenced by our observation that students and beginners acquire neither adequate details of knowledge nor relevant experience of simulation output analysis in traditional classroom learning. With the advances in the Internet learning environment, web-based computer-based training (CBT) can efficiently and effectively enhance the traditional classroom learning. This research addresses the issue of designing a web-based CBT course to assist the classroom instruction in helping students learn better simulation problem solving. The goal is to provide an effective way to learn the implicit experience of simulation output analysis via an efficient interactive environment. A prototype asynchronous web CBT system with simulation analysis guidelines was built to verify our design through a three-stage formative usability evaluation. The results showed that the simulation analysis guidelines organized by this research significantly improved the test scores and the interactive CBT system maintained students’ interests longer than the written format.

Keywords: Computer-based training; Formative evaluation; Simulation analysis; Web-based course; Tacit knowledge

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doi:10.1016/j.compedu.2003.11.005
1. Introduction

Computer simulation has been an important skill for a seasoned professional in operation research/management science (OR/MS) (Dyer, Bean, Dewald, Gepfert, & Odoni, 1993) and a critical OR tool in the industry (Nelson, Bradbard, Ledbetter, & Cox, 1987). A typical simulation process includes formulation, programming, verification, validation, experiment design and analysis, and recommendations (Taylor & Hurrion, 1988a, 1988b). Shannon (1985) estimated that one needs to receive “at least 720 h of formal class instruction plus another 1440 h of outside study” to acquire the basic simulation tools. This does not include the extra effort required to gain real-world experience in order to acquire proficiency.

Students in related fields usually take only one simulation course. Due to time constraints in classroom settings, learning computer simulation is often limited to simulation concepts, modeling and programming (Lu, 2000; Rohrer & Banks, 1998). Consequently, simulation design and analysis is simplified and receives a lower priority. The situation is further evidenced by our observation that most students consider simulation design and analysis a much more difficult topic. However, a successful simulation application depends heavily on the effectiveness of simulation statistical analysis. Thus, efficient learning of effective simulation statistical analysis merits more research.

Computer-based training (CBT) has been widely applied in learning after the burgeoning popularity of personal computer in the eighties. According to the survey of Whitehouse and Pellegrin (1995), utilizing personal computer and software to raise the knowledge of students can save up to 70% of training time. Recent popularity of Internet has brought more benefits into traditional CBT learning, such as the 24·7 availability, better interactions between students and instructors, and virtual classroom space. Accordingly, an asynchronous web-based CBT system can serve as an after-hour teaching assistant to traditional classroom learning.

Because the tacit knowledge of experiential simulation analysis is not included in major English textbooks, nor are these simulation-related CBT systems currently available to the public to our knowledge, the objective of this research is to explore the design of a web-based CBT system that can assist the beginners to study effective simulation analysis experience in an efficient way. The remaining paper is organized as follows: literature review in Section 2, research design and scope in Section 3, prototype system design in Section 4, and evaluations and conclusions in Section 5.

2. Literature review

A web-based CBT system on tacit knowledge is not common both in practice and in literature. Newman and Lamming (1995) indicated that the usability is the key for an interactive system design while Tao (1999) pointed out that the experience as well as the theory is required for learning proficient simulation analysis. Therefore, to meet the objective of such a CBT system design, we review the content of experiential simulation statistical analysis, the concept of interactive system design, and the characteristics of web-based CBT as follows.

2.1. Content of experiential simulation statistical analysis

Teaching both the knowledge and the experiences of simulation statistical analysis are required to help novice acquire effective problem-solving skills (Tao, 1999). Tao (1999) also pointed out
that experience is a broad term and the possible categories of simulation experience include high-
level simulation-analysis framework, practical simulation-analysis models, collections of simulation
tactics, case studies from the software companies, consulting firms or conference proceedings,
and useful simulation-analysis processes in the literature. Among these, framework, model, liter-
ature and case studies are materials that can be found in the references, while tactics are not.

Nevertheless, comparing to the methodology of simulation modeling and analysis, the practical
experience of simulation statistical analysis received less attention in the literature. Mellichamp
and Park (1989), Ramachandran, Kimbler, and Naadimuthu (1988), Taylor and Hurrion
(1988a, 1988b), and Tao and Nelson (1997) were the only few who had investigated simulation
analysis. They proposed some theoretical framework or prototype systems with different empha-
ses. On the applications, Goldsman, Nelson, and Schmeiser (1991) described their simulation
problem-solving processes that solved an airline reservation system problem using three different
approaches, all reaching the same conclusion. Tao and Guo (2000) proposed a mental model for
simulation statistical analysis, which included two cognitive guidelines, two design indicators and
a heuristic problem-solving process. Although the above experiences of simulation statistical anal-
ysis are precious, they cannot be easily organized for or shared during the classroom settings.

2.2. Concept of interactive system design

Norman (1986) proposed a seven-stage model of interaction development, including goals,
intention, action specification, execution, physical activity, perception, interpretation, and eval-
uation. The evaluation measures the final interpretation against the initial goal. Therefore, goal set-
ting is the most important foundation for any interactive system development. In response to the
importance of goal setting, Newman and Lamming (1995) pointed out that supporting activity,
form of solution, user, and level of support are important elements of problem definition, where
level of support specifies the usability goal. The targeted user’s involvement is essential for setting
the proper usability goal.

Newman and Lamming (1995) also proposed a method for conceptual design, which includes
identifying the form of mental model, hiding the mental model, encouraging the acquisition of this
mental model by providing a suitable system image, analyzing the design by means of detailed
cognitive walkthrough, and applications of design heuristic and guidelines. Targeted user group
is important to designers not only in coming up with an appropriate mental model but also in
focusing on providing an external system image that is usually the user interface in interactive sys-
tem environment. Cognitive walkthrough is a method for achieving the appropriate system func-
tionalities, and is comparable to the three-stage goal of an information system processing (Sauter,

When the designer is not familiar with conceptual design, he may apply empirical laws or guide-
lines when designing an interactive system (Shneiderman, 1992). Knowing, selecting, and applying
design guidelines are very important as design guidelines may have supplemental, conflicting, or
overlapping effects. When one applies too many design guidelines, the marginal effect shows.
Therefore, the guideline in applying design guidelines is to select the minimum number of design
guidelines required for achieving acceptable usability goals.

Good references for design guidelines, such as traditional man–machine interface design guide-
lines (Shneiderman, 1992), web page design guidelines (Nielsen, 2000), and bloopers (Johnson,
are adequate for a good practical interface design. As the central idea of evaluation is to support the design, formative evaluation is preferred (Preece et al., 1996). Consequently, evaluation involves a repeating process of system testing, and promotes forming a solution to the design problem.

2.3. Characteristics of web-based CBT

Due to the rapid growth of Internet, web-based CBT, distance education, distance learning, and e-learning are becoming synonymous. Harris (1999) pointed out that the United States has a tremendous growth for technology-mediated distance learning because the need was high and the technology was here. Ubell (2000) referred to a research result and an on-campus experiment to show that students can learn on line as well as they do on campus. However, Ubell (2000) also referred to some criticism which blamed schools for rushing into distance learning by offering inexpensive “plug and pay” courses, and claimed that online learning cannot replace life on a real campus. Wiesner (2000) contributed the rise of web-based courses to the historical developments of distance education and computer-assisted instruction (CAI), and debated whether today’s distance education is a rebottling or a new brew. Similarly, Ausserhofer (1999) drew attention to some of the limitations and pitfalls in web-based education as a major field of research and a hot area of applications.

Because content rather than technology is becoming a paramount concern for Web publishing, Kostur (1999) emphasized the importance of managing a web-based learning project for ultimate result. Danchak, Jennings, Johnson, and Scalzo (1999) proposed a web-learning model that was composed of 80% of asynchronous learning and 20% of the synchronous learning for better learning experience. The driving forces behind their 80/20 model were three learning models, including Gagné’s nine instructional events (Gagné, Briggs, & Wager, 1988); the cycle of distance learning which was proposed by Parker et al. and consisted of humanizing, participation, delivery, feedback and evaluation (Parker, Hough, & Parker, 1996), and Kolb’s learning style inventory (LSI) (Kolb, 1984). The nine instructional events listed by Gagné et al. (1988) include guiding attention, informing learners of the lesson objective, stimulating recall of prior learning, presenting stimulus materials with distinct features, providing learning guidance, eliciting performance, providing informative feedback, assessing performance, and enhancing retention and transfer.

As web-based CBT began to evolve, different forms and level of interactivity were experimented. Zu and Chang (1998) organized the taxonomy of learning styles for CBT, including constructive learning, situated learning, case-based learning, apprenticeship learning, project-based learning, story-based learning and collaborative learning. One example of web-based CBT systems with interactive design is a dynamic guidance using quiz functions for web education, which uses functions of on-line quiz, student profile, dynamic student grouping, and user interface agent to provide interactive guidance function during learning (Okada, Tarumi, & Kambayashi, 2000). Another example is a hybrid course delivery model emphasizing the involved activities, in which hands-on experience and mini-lecture are two major components (Siddiqui & Zubairi, 2000).

3. Research design and scope

Based on the literature review, this research intends to address the design, the development and the formative evaluation of a web-based CBT system containing the tacit knowledge of experiential
simulation analysis. Accordingly, the problem definition with intended goals is first defined, and
the user profile is carefully sketched. With the goals and user profile identified, the core model of
the experiential simulation analysis and the selection of interaction system design guidelines are
introduced. The plan for the formative evaluation is then explained at the end.

3.1. Problem definition

The research problem was “to design an efficient yet effective web-based CBT course to assist
the simulation novice learn simulation tactics in conjunction with the traditional classroom learn-
ing”. The design of this web-based CBT course focused on the experiential part of simulation sta-
tistical analysis and the learning-enhancement interactions. The target users were college students
with basic statistical training and had learned or were in the process of learning simulation.

The goal of effectiveness was accomplished by embedding simulation statistical expertise in the
CBT course, while the goal of efficiency was achieved by combining the learning of basic knowl-
edge of simulation analysis in-class and the learning of simulation statistical expertise online.

3.2. User profile

In order to guide the design to meet the usability goals, we first profiled the targeted user group
on their personality traits, knowledge and tasks experiences based on our observations: the user
was computer literate but might not be at the expert level, had web experience but minimum con-
tacts with web learning systems, had knowledge of introductory probability and statistics but
might not be familiar with statistical software, liked to practice during learning, cared more about
quality but not quantity of learning, wished to gain problem-solving skill in a short period of time,
and was interested in learning simulation statistical analysis in a less stressful environment.

3.3. Model of experiential simulation analysis

The tacit knowledge of experiential simulation analysis was designed as a three-level model,
including contextual problem-solving guidelines, problem-solving process and learning-unit de-
sign, according to their roles in this CBT system. Contextual problem-solving guidelines were
the finest tactics the expert applied to solving a problem, and were embedded in the problem-solv-
ing process specifically designed for the novice. The learning-unit design presented the segmenta-
tion of the learning contents, which included both the guidelines and the process.

This three-level model modularized the problem-solving guidelines and mapped them into
either the problem-solving process or the learning-unit design. Therefore, it could easily provide
a customized learning experience for novice through a mixture of what Zu and Chang (1998)
called constructive learning, situated learning and case-based learning. In particular, the situated
learning was incorporated into the case-oriented learning as focused scenarios.

3.4. Interaction design guidelines

As indicated in the literature review, design guidelines provided a designer suggestions and
solution strategies to the design problem. The challenge was to select, apply, and confirm a set
of design guidelines that aggregated to an acceptable level of usability goal. Based on our previous experience and study (Tao, 2000), we decided that the best approach for adopting design guidelines in this prototype system development is the trial-and-error approach and hoped to achieve 80% of intended goals with a minimum set of guidelines. This research applied instructional design guidelines proposed by Gagné et al. (1988) and interface design guidelines proposed by Zu and Chang (1998), Dix, Finlay, Abowd, and Beale (1998), Marcus (1992) and Shneiderman (1992). We also applied self-inducted guidelines from experiences and observations over the Internet.

3.5. Evaluation design

This research used formative evaluation to avoid finding critical problems after the prototype system development was completed. The three-stage formative evaluation, including user’s testing evaluation, experts’ constructive and executive evaluation, and user’s summative evaluation, is described as follows:

(a) **User’s testing evaluation.** The purpose was to conduct an informal evaluation on the initial design of the teaching system and the interface, so that users could provide feedback on any discrepancies as much as possible and as early as possible. The data sets were collected by means of observation and audio recording from students browsing through the initial prototype system. Retrospective interviews and verbal protocol analyses were also performed to obtain qualitative data.

(b) **Expert’s constructive and executive evaluation.** The internal validation checks of the learning material were performed by the research team. It included two simulation-analysis professors who developed the conceptual model as well as the learning contents, and a graduate student collected and organized the learning contents from several major English simulation textbooks under the guidance of the two professors. The purpose of this stage was to evaluate the contextual design, instructional style and interface design from external experts’ perspective. The data sets were collected from three experts’ heuristic evaluation. Retrospective interviews were performed for qualitative data.

(c) **User’s summative evaluation.** The purpose was to understand the usability and learning effects of the final prototype system implemented for this research. The targeted subjects were beginners who had one year of probability and statistics, and one simulation class. Within their simulation class, simulation problem-solving in modeling, statistical analyses, simulation graphical software such as ARENA were covered. The subjects were divided into the control group who studied the written material and the experiment group who operated the CBT system. The written material and the CBT system covered the same simulation expertise prepared by this research but in different learning styles. The evaluation first compared all subjects’ test scores for their performance differences before and after the learning session. Then a usability survey about the prototype system was conducted with the experiment group. The test questions were typical decision-support analysis for comparing different alternatives in, for example, plant layout, waiting line setup, and inventory policy. The learning contents included typical scenarios in a simulation problem-solving task, such as simulation run length, random number streams selection, statistical methods decisions, and so on. Evaluation results were analyzed quantitatively.
4. Design of prototype

Based on the definition of the research problem, we designed a prototype system for this research. The design of the prototype system is as sketched in Sections 3.3 and 3.4, including the contextual problem-solving guidelines, the problem-solving process for novice, the learning-unit design, and the applied interaction design guidelines and demonstrations.

4.1. Contextual problem-solving guidelines

Certain simulation concepts, such as initialization bias in the steady-state system, correlated data, and time-persistent variables, are not easily comprehensible to information-technology capable practitioners. To speed up the learning process, this research developed problem-solving guidelines based on the framework and the concept of sequential experiment from Tao and Nelson (1997) and expert experiences from Goldsman et al. (1991) and Kleijnen (1987). The guidelines collected and organized by this research is listed in Fig. 1 and they were classified into six categories as defined below:

1. **Paradigm:** The goal of the paradigm was to provide practitioners a correct mindset about simulation problem-solving analysis, which is an incremental and data-driven process.
2. **System/parameter/system instance:** A system is a black box with one or more parameters and takes prescribed input to produce corresponding output. A system instance is a system with a set of fixed values of the system-dependent variables. Parameters are a collection of constants that define an instance of a system.
3. **Design/experiment/resource:** A design is subject to various resource constraints and consists of the number of replications, the stopping time for each replication, the random number assignment, and the data aggregation technique.
4. **Output data:** A user should utilize simulation data carefully in order to get more out of statistical analysis.
5. **Statement/scopelresult:** Results at various stages of the simulation sequential analysis have different scopes and applications. Therefore, the user can record results as statements for further references.
6. **Analysis/procedure:** An analysis derives statements about systems while a procedure is a function of data and statements that produces a new statement.

The above six categories of experiential guidelines were not comprehensive due to references and time constraints. But we considered them adequate for this research to validate the experts’ problem-solving processes and to derive a simple and useful flow to assist the learning of an online simulation analysis system.

4.2. Problem-solving process

The principle of the conceptual design is to identify the intended mental model and hide the complex insight by providing a simple representation (Newman & Lamming, 1995). Therefore, we have simplified the expert’s problem-solving model as shown in Fig. 2 The web-based system
is intended for use after the simulation model is constructed. Thus the model starts with multiple system comparison and includes some of the experiential guidelines listed in the preceding section.

Step 1 judges the type of system and may apply guideline 2-1. Step 2 decides on a project to start with and may apply guidelines 2-3 and 2-4. Steps 3 and 4 determine whether or not to apply variance reduction technique (VRT), such as Common Random Number (CRN). Step 5 simulates minimum data for planning next design and may apply guidelines 1-1 and 1-2. Step 6 enters the pilot run procedure that starts with experimental design (guidelines 3-1, 3-2, 3-3, and 3-4), followed by simulation execution and output data analysis (guidelines 2-2, 4-2, 6-3, and 6-4). At the end, guideline 4-1 may be used to judge whether remaining execution time is enough. Step 7 compares alternative systems and draws conclusions based on guidelines 5-2, 5-3, and 6-2.
The above process is based on the multiple system comparison. For single system evaluation, the process still starts with Step 1, but skips Step 7. The purpose of this problem-solving process is to incrementally design and evaluate simulation problems. It is intended to be a simplified ex-

Fig. 2. Problem-solving flow of simulation analysis.
pert model for beginners and emphasizes learning problem solving while building an appropriate mental model.

4.3. Learning-unit design

The learning environment includes five major instruction units: learning guidance, introduction to simulation, simulation theory, design strategy, and case-oriented learning. Learning guidance provides a roadmap for three different skill levels of users. Introduction to simulation briefly introduces simulation characteristics, applicable domains, and its pros and cons. Simulation theory presents fundamental simulation knowledge that includes theory and techniques in input/output data analysis. Design strategy includes both the problem-solving guidelines and problem-solving process as described in Sections 4.1 and 4.2. Case-oriented learning assists the users to learn from solving a problem using embedded guidelines and expert process. This is the major interaction method designed to enhance learning in this research. The prototype system also included student record management, message board, and online discussion.

In summary, the above learning units constitute an integrated learning framework that emphasizes both the knowledge and experience during the learning process. The focal point is on the problem-solving guidelines, problem-solving process, and case-oriented learning units to maximize the effectiveness of the system.

4.4. Interaction design guidelines and demonstrations

We present two screen shots to illustrate the primary interaction design guidelines.

4.4.1. Example 1: Fig. 3

The left side of screen shows the five teaching units (circle A). The discussion of the right side of the screen is divided into eight parts as follows.

(1) The upper screen shows the path of the learning contents (circle B), “case-oriented learning > single system instance > steady state > start simulation > determining sample size”, which not only indicates current position, but also provides hyperlinks to previous screens.

(2) Clicking on the palm-like image near the right edge of the screen (circle C), a window pops up that explains the purpose of current page. This applies the guideline for providing instant online help on an as-need basis. The first two parts, (1) and (2), apply guidelines of avoiding lost, reducing short-term memory load, stimulating recalls of prior learning and providing convenience reversal browsing.

(3) The center of the main screen displays the dialog between the user and the system. As indicated by the path in (1) above, the current step is determining the initial sample size at the very beginning of the simulation process. The system prompts the user to decide the sample size and simulation time. The user can click on the hyper-linked phrases “sample size” or “simulation time” (circle D) for explanations before making decisions. The applicable guidelines are providing online help for critical terminology and hiding unnecessary information.
4.4.2. Example 2: Fig. 4

Fig. 4 displays a similar screen as shown in Fig. 3 except without the palm-like image and the red color question. The purpose is to be consistent and providing only necessary information or functions.

(1) The bottom of the screen shows a pink question mark (arrow A). Clicking the image will pop up the explanation (of initial bias detection) for that option. It is a similar function like the palm-like image in Fig. 3 but only applicable when the user needs to choose the next step. The applicable guideline is also providing instance online help on a needed basis.

(2) Either the palm-like image or the pink question mark provides optional online help. However, the user may not know their usage at the first glance. Therefore, the system provides balloon help (arrow B as shown in the bottom edge of the screen) that offers a brief explanation when the cursor is near the image. The purpose is to provide interactive proactive clues.

(3) The screen layouts in Figs. 3 and 4 address the concise guideline by adapting the following features: page-long content, short paragraphs, wide spacing between paragraphs and sentences, hiding unnecessary information with hyperlink, color segmentation, hierarchical information with selection buttons, and primary information in the middle with bright background color.

(4) In order to retain user’s learning interests for long hours of complicated and difficult domain knowledge and experience, the system embeds cartoon or scenic images in the learning activities as well as background music to entertain the users.
Fig. 3. Sample screen #1 (translated from Chinese).

Fig. 4. Sample screen #2 (translated from Chinese).
5. Evaluation and conclusion

We present the results of the three-stage formative evaluation and conclude this research at the end.

5.1. Testing evaluation

This stage evaluated the early prototyping system through observation and interviewing of users, who each performed a 50-min experiment as shown in Table 1. Since this was a developmental stage evaluation, the goal was to validate whether the design concept met the users' needs. Therefore, only two subjects participated in the experiment.

Table 2 summarizes the evaluation results. The first subject, who had a simulation course, focused more on the content and had responded with 12 questions. The second subject, who never had a simulation class, was interested in the interface and had more questions about the color design and the layout. On the content, the first subject clearly knew what to expect and thought that some descriptions of simulation concepts were too tedious and the wording should be more precise, while the second subject was obviously troubled by many unfamiliar terms. On the color design and the layout, the second subject endorsed the use of buttons, lists, and tables, while the first subject’s main concern was the colors of the text. Most suggestions had been modified in later versions of the prototype system.

5.2. Constructive and executive evaluation

This stage of evaluation was conducted after the framework of the prototype system was drafted with little details. The goal was to understand the learning material and the appropriateness of the teaching and interface design. Four domain experts participated in the evaluation of the prototype framework. Each expert explored the system differently with an average time of 80 min. Opinions were collected during the operations and interviews were conducted after the operations.

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Purpose</th>
<th>Subject</th>
<th>Facilitator</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10</td>
<td>Let the subject understand the evaluation purpose and the operation process</td>
<td>Understand evaluation purpose and operation process</td>
<td>Explain evaluation purpose and operation process</td>
<td>Personal computer</td>
</tr>
<tr>
<td>10–20</td>
<td>Let the subject be familiar with the evaluation process</td>
<td>Practice and think aloud</td>
<td>Instruct subject how to perform think aloud</td>
<td>Personal computer</td>
</tr>
<tr>
<td>20–40</td>
<td>Evaluate the system</td>
<td>Operate system and think aloud</td>
<td>Observe and record</td>
<td>Personal computer, paper and pencil, audio recorder</td>
</tr>
<tr>
<td>40–50</td>
<td>Compare different design guidelines</td>
<td>Operate system and answer questions</td>
<td>Interview, observe, and record</td>
<td>Personal computer, paper and pencil, audio recorder</td>
</tr>
</tbody>
</table>
Table 2
Summary table for testing evaluation

<table>
<thead>
<tr>
<th>Problem category</th>
<th>Subject #1</th>
<th>Occurrences</th>
<th>Subject #2</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Color of content</td>
<td>3</td>
<td>Color of content</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Flashing buttons are good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Button color makes text not obvious</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highlighting color not distinguishable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Font and font size</td>
<td>Improper choice of font type</td>
<td>6</td>
<td>Improper choice of font type</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Could use different fonts</td>
<td></td>
<td>Font size too small</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Font size too small</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Editing and layout</td>
<td>Monotonous</td>
<td>10</td>
<td>Too lively</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Lively</td>
<td></td>
<td>Need to increase dynamic feelings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex</td>
<td></td>
<td>Good use of itemization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Need more images</td>
<td></td>
<td>Good tabular presentation</td>
<td></td>
</tr>
<tr>
<td>Image</td>
<td>Uninspiring</td>
<td>6</td>
<td>Uninspiring</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Text in image is difficult to read</td>
<td></td>
<td>Image not clear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Text in image is difficult to read</td>
<td></td>
<td>Text in image is difficult to read</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Wording is too causal</td>
<td>12</td>
<td>Too many unfamiliar terminologies</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Too much, too tedious</td>
<td></td>
<td>Overloaded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unclear terminology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insufficient explanations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning design</td>
<td>Lost the direction</td>
<td>8</td>
<td>Cannot go back to previous pages</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Complicated hierarchical linking</td>
<td></td>
<td>Don't know where to start</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Don't know where to start</td>
<td></td>
<td>Don't's know what the button is for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cannot go back to previous pages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Data transmission is too slow</td>
<td>3</td>
<td>Data transmission is too slow</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3 summarizes the collected problems and shows that experts responded more on the multimedia presentation and content materials. Some experts suggested that background music might be a distraction and the user should be able to switch it off. Another expert suggested that simulation software images and animation icons could be used in addition to cartoon-like graphics. Other suggestions included adding new materials to increase the depth of the system. However, adding fundamental concepts in order to accommodate students without any simulation course is beyond the scope of this research. All other suggestions were modified accordingly for next stage of testing.

5.3. Summative evaluation

We conducted a user evaluation to 30 university students who had a 3-credit-hour simulation introductory course. The students were divided into a control group and an experiment group with the control group studying a written material, while the experiment group operating the CBT prototype system. Each session was 60 min long and included a 10-min introduction, a 10-min simulation test, a 30-min simulation learning, and another 10-min test. The experiment
Table 3
Constructive and executive evaluation summary table

<table>
<thead>
<tr>
<th>Problem category</th>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>Functional display</td>
<td>Provide bubble help to some graphical buttons when the pointer is near</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The pointer does not change to a hand when pointing at some buttons</td>
</tr>
<tr>
<td>Program software presentation</td>
<td>Explanative diagrams</td>
<td>Text in image is not clear</td>
</tr>
<tr>
<td></td>
<td>Font color</td>
<td>Color of some hyperlink texts is inadequate</td>
</tr>
<tr>
<td></td>
<td>Content volume</td>
<td>Some headings are too long, not concise</td>
</tr>
<tr>
<td></td>
<td>Background music</td>
<td>It is unnecessary to have music on every page</td>
</tr>
<tr>
<td></td>
<td>Animation</td>
<td>Too little animation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can add animation screens of simulation software</td>
</tr>
<tr>
<td>Correctness of material</td>
<td>Sample design</td>
<td>Exchange event column with customer number in Table “Simulation Characteristics” because users are more concerned with messages in the event column Add customer tolerance time before balking in the steady state example</td>
</tr>
<tr>
<td></td>
<td>Material selection</td>
<td>Add basic concepts of simulation for novice to use this system as well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Add an introduction of random numbers generation</td>
</tr>
<tr>
<td></td>
<td>Material difficulties</td>
<td>The “in-depth understanding” unit is too difficult to most users and should be placed after “case-oriented learning”</td>
</tr>
<tr>
<td>Web design</td>
<td>Location</td>
<td>Where am I? How can I return to previous pages?</td>
</tr>
</tbody>
</table>

group filled out one additional questionnaire regarding the design of the prototype system. Based on the usability goals of efficiency and effectiveness, we divided the evaluation analysis into system design usability analysis and learning performance usability analysis. The system design usability analysis was based on subjective interface opinions. The learning performance usability analysis was based on objective learning scores of the control group, the experiment group, and the overall population.

5.3.1. System design usability analysis

The questionnaire for the web-based learning system was designed based on the CAI program software evaluation rules by Du (1991). Questions were divided into four constructs of operation, program software, correctness of material, and feedback handling. A Likert-type scale ranging from very good (+2), good (+1), average (0), bad (−1) to very bad (−2) were used. Cronbach α coefficient and content validity coefficient proposed by Lin (1993) were used. Table 4 showed both reliability and validity of the questionnaire were acceptable.

Although problem constructs did not show significant difference, most values in Table 5 were positive and implied most subjects approved the system design. Input operation, function display, selected examples, and terminology explanation were rated to be most appropriate. Recall that the first stage of evaluation had indicated that some terminology explanation was unclear or tedious
and the experts also raised problems about the function display. This revised version of the CBT system clearly corrected those problems. Item received negative values included volume of images, depth of material, and variations of feedback (volume). We agree that more visually appealing images are needed to enhance the appearance of the system. One can expect a low score for the depth of materials, since most students considered that simulation is difficult and most of the selected materials were not discussed in details in the traditional classroom setting. We also agree that the prototype system needs to enhance its variation in feedback.

In addition, some items were positive but close to zero, such as the visual enhancement and freedom to select explanations. The first item was highly correlated with volume of images used. We also believe that adding more images will visually improve the appearance of the system. The second item can be attributed to the observation that most subjects were confused when facing difficult scenarios and not realizing that some images were hidden buttons for explanations. This situation can be improved by adding mouse-over bubble help.

Table 4
Reliability and validity

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Questions numbers</th>
<th>Reliability coefficient</th>
<th>Validity coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>1–3</td>
<td>0.8579</td>
<td>0.9262</td>
</tr>
<tr>
<td>Program software</td>
<td>4–11</td>
<td>0.7505</td>
<td>0.8663</td>
</tr>
<tr>
<td>Correctness of material</td>
<td>12–15</td>
<td>0.4444</td>
<td>0.6666</td>
</tr>
<tr>
<td>Feedback handling</td>
<td>16–20</td>
<td>0.6299</td>
<td>0.7936</td>
</tr>
</tbody>
</table>

Table 5
Summative evaluation summary

<table>
<thead>
<tr>
<th>Question</th>
<th>Accumulated score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input operation is appropriate</td>
<td>9</td>
</tr>
<tr>
<td>Function display is clear</td>
<td>10</td>
</tr>
<tr>
<td>Function display is appropriate</td>
<td>6</td>
</tr>
<tr>
<td>Screen layout and objects (button or frame) are appropriate</td>
<td>7</td>
</tr>
<tr>
<td>Explanations for diagrams are clear</td>
<td>3</td>
</tr>
<tr>
<td>Image enhancement is appropriate</td>
<td>0</td>
</tr>
<tr>
<td>Volume of images is appropriate</td>
<td>-3</td>
</tr>
<tr>
<td>Font size is appropriate</td>
<td>6</td>
</tr>
<tr>
<td>Font color is appropriate</td>
<td>5</td>
</tr>
<tr>
<td>Text arrangement is appropriate</td>
<td>2</td>
</tr>
<tr>
<td>Feedback display is appropriate</td>
<td>2</td>
</tr>
<tr>
<td>Material selection is appropriate</td>
<td>-5</td>
</tr>
<tr>
<td>Difficulty of material is appropriate</td>
<td>-3</td>
</tr>
<tr>
<td>Selected examples are appropriate</td>
<td>9</td>
</tr>
<tr>
<td>Terminology explanation is clear</td>
<td>8</td>
</tr>
<tr>
<td>Variations of feedback are appropriate (volume)</td>
<td>-1</td>
</tr>
<tr>
<td>Timing of feedback is appropriate</td>
<td>4</td>
</tr>
<tr>
<td>Prompt explanation is clear</td>
<td>6</td>
</tr>
<tr>
<td>Freedom to select explanations</td>
<td>1</td>
</tr>
<tr>
<td>Hierarchical explanations</td>
<td>5</td>
</tr>
</tbody>
</table>
5.3.2. Learning effects evaluation analysis

Learning performance analysis is based on the student’s subjective opinions and the objective test scores before and after the learning period. The test scores after the learning period showed significant increases. This suggests that the intended simulation tactics in Section 4.1 are useful for assisting learning simulation analysis.

Although the experiment group did marginally better, the $t$ test applied on the test scores after the learning period did not find significant difference between the two groups. That is, learning the prototype CBT system led to little improvement on the test scores. We suspect that the 30-min learning period may not be long enough to detect possible differences. We must also point out that the experiment might produce stronger results if the evaluation were conducted with a problem-solving format on more realistic cases instead of easily memorized questions-and-answers format.

The additional questions in the second test indicated that two items “boring” and “interesting” had significant differences between the two groups with $z = 0.05$. That is, the experiment group felt more interest and fun learning simulation analysis via the CBT system. This suggests that the prototype system retained the learners’ motivation better than the written format and if learning time were increased, the experiment group may start showing significant improvement on test scores. Furthermore, the interactions on the prototype system provided options for constructive learning that could not be included in the written format.

Even though the $t$ test showed insignificant difference on the “convenient” item between the two groups, the data revealed that more subjects in the control group favored the format they used. Some of them stated that the written format can be easily browsed through or carried around. Since the material contains most of the same simulation content as the prototype system, we feel that a good option is to make written material downloadable to students using the CBT system.

5.4. Conclusions

This research developed a CBT system to assist the students learning simulation output analysis, which is considered to be more difficult than the simulation modeling. The summative evaluation verified that the simulation tactics we developed did achieve significant improvements on test scores in either the CBT or written format. Although not directly supported by the test scores, the evaluation showed that the case-oriented learning interactions and design guideline-oriented interface retained learning interest better than the written format. Subjects also favored the convenience of written materials due to its portability. A major implication of the above results is that if normal classroom materials can supplement the simulation statistical expertise, students should be able to learn simulation problem-solving skill more effectively from the start. Moreover, if the supplemental material can be presented in a web-based CBT format, students should be able to achieve the same level of understanding more efficiently.

Acknowledgments

This research project was partially sponsored by National Science Council of the Republic of China with Grant No. NSC 87-2218-E-214-013. The authors thank the editor’s valuable comments for making this paper better presented.
References


