A Web Simulation on Educational Change: Challenges and Solutions for Development

Theodore W. Frick, Indiana University*

Kyong-Jee Kim, Indiana University

Barbara M. Ludwig, QUALCOMM

Rui Huang, Indiana University

* Correspondence about this article should be addressed to
Theodore Frick, Department of Instructional Systems Technology, School of Education,
Room 2218, 201 N. Rose Ave., Bloomington, IN 47405. 812/856-8460, or by e-mail, frick@indiana.edu

Abstract

The Diffusion Simulation Game (DSG) was created to provide graduate students in the Instructional Systems Technology (IST) Department at Indiana University with an opportunity to play the role of a change agent charged with bringing about innovations in teaching methods at a fictional junior high school. Originally created by an IST faculty member in a paper-based format, the game consists of a game board and several information and feedback cards. To play the game, teams of three to four students work together to develop a strategy for persuading as many people as possible to adopt a particular innovation. This game has formed an integral part of a core, residential IST course since the 1970s. In 2001, the IST Department decided to offer this course for the first time online, and thus needed the paper-based version to be converted to a Web-based medium. We began by conducting a needs analysis of the stakeholders (course instructors and past students) for the Web-based DSG. Next we developed a rapid prototype (Web mock-up of what the game might look like in a browser) and conducted some usability tests in order improve the DSG design. After several design iterations, we then created a computer prototype using PHP (a Web programming language) and XML (Extensible Markup Language) with HTML to provide the interactivity of the game in which learners make decisions and experience their consequences. We also conducted two rounds of usability tests with target users to evaluate and improve the design of the working computer prototype. The final product was embedded into a distance education course after four months of development. We will discuss our initial evaluation results, and the overall impact of the online game on the distance students and the course in general. Finally, we will discuss ongoing maintenance and plans for the future of the DSG and its implications for developing a simulation to teach systemic change in education.

Introduction

The Diffusion Simulation Game (DSG) was originally designed for a graduate-level class in the Instructional Systems Technology (IST) Department at Indiana University. It was designed to provide graduate students with an opportunity to simulate the role of someone charged with bringing about changes in teaching methods at a fictional junior high school.

Originally created by an IST faculty member in the paper-based format, the game consists of a game board and several information and feedback cards. To play the game, teams of three to four students work together to develop a strategy for persuading as many people as possible to adopt a particular innovation (Molenda & Rice, 1979). This game has formed an integral part of a core, residential IST course since the 1970s.

In a typical setting, students played the game as a group with 3-4 students for duration of 1 hour. While playing the game the students work together to choose a strategy to persuade people to adopt an innovation and write down the strategies they used and the number of people who were successfully adopted the innovation. After completing the game, the instructor provides a debriefing session, in which students reflect on how the strategies they used affect the success and failure of the simulated diffusion of educational change.

In 2001, the IST Department decided to offer this course for the first time online. It was virtually impossible to use a paper-based DSG to teach distance students. Thus, paper-based version needed to be converted to a Web-based medium. The Web-based DSG came into use in 2002 after a four-month development process. The game is currently being used in the distance and residential versions of a core class of IST. In this paper we will describe the process of converting the paper-based DSG into a computer-based version. We'll also discuss the challenges that we encountered and the solutions we came up with to create this online simulation game.

DSG is now available on the Web at the following URL: http://www.indiana.edu/~istdemo/dsg/login.phtml. Currently an Indiana University network ID is required to log in to this Website. The development team is working to make it available to the general public as well. The general public is expected to be able to log in to this Website by obtaining a guest account from Indiana University's central authentication system in the near future.

Procedures

In spring of 2002, a development team was formed to develop online DSG. The team consisted of three graduate students in IST and the first author who is a faculty member of IST. The game was developed as a course project in an advanced production class. The development process followed steps outlined by Frick and Boling (2002) for effective Web instruction, an inquiry-based process.

Needs Assessment and Product Design Requirements

We conducted interviews with the stakeholders to identify the needs for the design and development of the Web-based DSG. This included interviewing the faculty member who originally developed the game and has been using it in the residential course, and the faculty/student team who was planning to offer the online version of the class that summer. From those interviews, we gathered information on the target audience and the context and requirements for learning. Stakeholders expected the game to be delivered via the World Wide Web (as opposed to CD-ROM). The instructors expected that a history of each student's game play be kept for use in debriefing. The DSG game typically takes more than two hours to play, so we needed to design it so that students could pause and resume the game from where they left off, even at a different computer. Also, since it was difficult for distance students to work as *a group* to play the game in real-time, the new online DSG was designed for a single player.

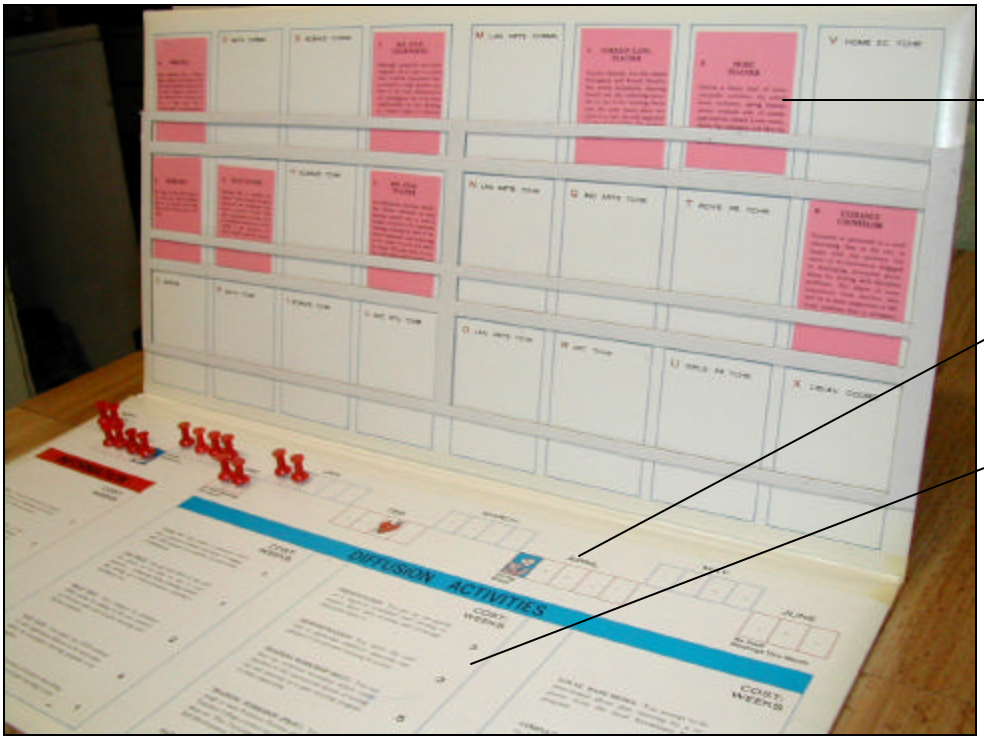
Design

Our aim was to transfer the paper-based game, which required a big table to place the game board, information cards, feedback cards, adoption form, instructions, and list of strategies onto a computer display whose size would be a minimum of 800 x 600 pixels. The main challenge of the interface design was to put the four major components of the paper-based version of the game (the game board, adoption form, information cards, and feedback cards) onto one dynamically changing Web page as the game progressed. A comparison between the structures of paper-based game and the Web-based one is shown in Table 1. Also, a picture of the paper-based game board and a screenshot of the online DSG page are shown in Figures 1 and 2.

Table 1. Comparison between paper-based and the Web-based DSG

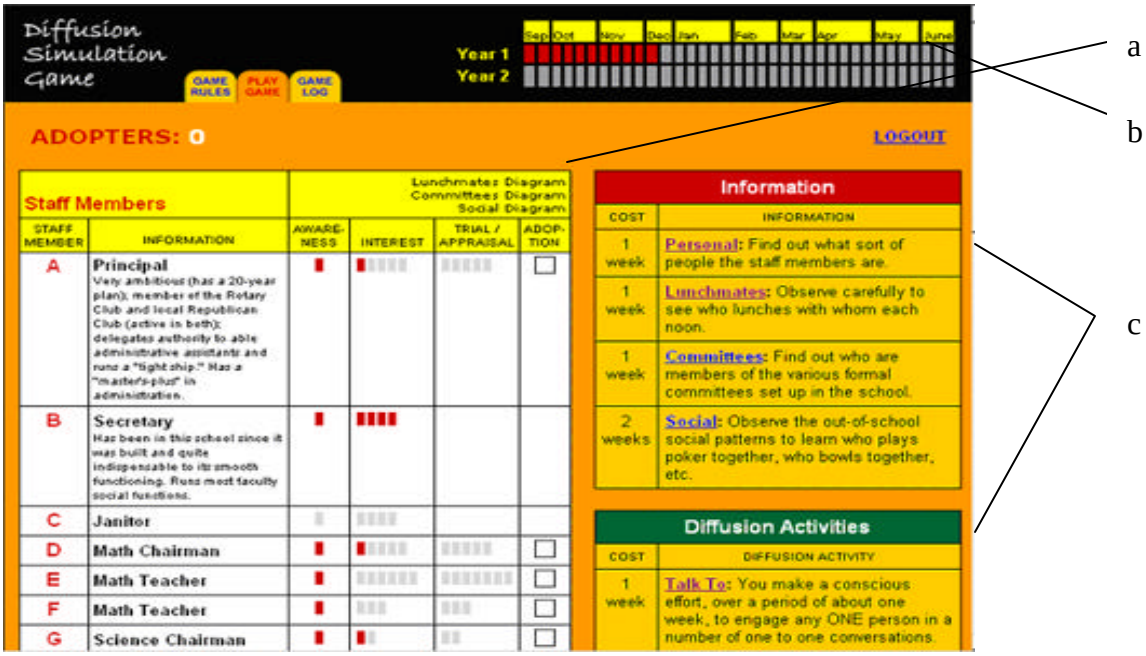
Components of paper-based game	Web-based game solution
1. Instructions for the game.	1. "Game Rules" page has detailed information about the game.
2. Game board – present available information and diffusion activities; store information cards; record passing time.	2. "Play Game" page – in which a calendar, characters list, information about strategies, and information gathered by the player are presented.
3. List of strategies – record strategies used and feedback on them.	3. "Game Log" page shows the history of the game, which includes information about strategies used and corresponding feedback.
4. Adoption form – record "influence points" for each character and adopters.	4. Adoption form is combined with the list of characters on the left side of the "Play Game" page.
5. Information cards – have detailed information about each character in the game.	5. Information about each character is stored in an XML file, which can be retrieved on the "Play Game" page after a player's selection.
6. Feedback cards – feedback on strategies users take from game facilitator.	6. Feedback is stored in XML files, which can be selected by the computer according to a player's decision and shown on "Play Game" page.

Figure 1. Paper-based DSG



A – Information cards
B – Calendar
C – List of information and diffusion activities

Figure 2. A screenshot of the "Play Game" page of the Web-based version of the DSG



a – Information cards are embedded into the adoption form
b – Calendar shown on the top of the page
c – List of information and diffusion activities

As the first step in this design process, we created a HTML-based mockup to design the interface of DSG. The concept of rapid prototyping (Boling & Frick, 1997; Frick & Boling, 2002) was used in this process as an iterative design approach. In this approach, the prototype is created on paper before it is developed on the computer so that the developer can test it out with the target users very early in the process. This iterative approach to design and development allows developers to evaluate and improve the design of the product early in the process. In this case, we created a mock-up HMTL Web page instead of the paper prototype due to fact that the game had been played on "paper" as a board game for many years in IST classes.

Then, we conducted several usability tests to evaluate and improve the design of the mock-up Website. The prototype was checked at various stages so that errors could be detected in the early stages. Usability testing is a process which involves observing the interaction of users representative of the target population with a product in order to identify and rectify usability problems (Rubin, 1994). Among existing usability testing protocols, we adopted the usability testing process by Frick and Boling (2002). We conducted usability tests of the DSG prototype with four graduate students in IST. Through this round of usability testing, some problems about the interface, diagrams, language are found and corresponding revisions were made of the HTML mock-up pages.

Development

A working computer prototype was produced in the development phase. For the paper-based game, a game facilitator is needed to give information game players require and feedback based on game rules to players' activities. Similarly, in a Web-based game, a server is needed to act as the facilitator and server-side programming is required. Another challenge was that unlike a paper-based game, which can provide several game boards to different player groups at the same time, there is only one game on one server. Therefore, data for different users had to be stored and differentiated.

To address those challenges of interactivity and data restoration, we decided to create recursive Web pages using PHP and XML. PHP (PHP Hypertext Preprocessor) is a server-side programming language that allowed us to create dynamically generated Web pages. Using PHP, it was possible to store the data of the game strategy, process it according to the game rules, and display the results on the Web page. Another reason that we used PHP instead of other server-side programming languages (e.g. ASP, JSP) is Apache - the server PHP works with most commonly - is free. Second, XML (Extensible Markup Language) is a document encoding or markup standard. We used XML to simplify and organize the structure of the feedback pages by storing and retrieving the information in extensible document elements. XML was also used to store user information in order to resume the game at any time from any computer.

Usability Evaluation

After developing the computer prototype, we demonstrated it to the stakeholders to solicit their feedback on the product. In addition, we conducted a second round of usability tests with target users. Four graduate students in IST at Indiana University participants in these usability tests. Here, we used the same protocol for usability testing as we did in the first round of usability tests. We discovered some minor programming errors and interface design problems from those tests and the prototype was revised to resolve those problems.

Implementation

After the four-month design and development process, the product was introduced to distance students in the summer, 2002. The distance students played the simulation individually and had a group discussion for debriefing using an asynchronous online communication tool. During the debriefing, they had access to their game history via log pages which used PHP and XML to track the different diffusion strategies and tactics they had used during game play.

The paper-based DSG, which had been used in a section of a residential core IST class, was also replaced by the online version 2003. The instructors took the advantage of this online game by not having to bring the bulky paper game sets to the class. Students also benefited from playing this game online, too. Distance students were able to play DSG at any place and at any time over the Web. Residential students seemed to enjoy playing this interactive online game, which was revealed by their reactions on playing the game from the evaluation data.

Evaluation

According to Kirkpatrick (1994), there are four levels of evaluation: reaction, learning, behavior, and results. For the DSG, we focused only on the first two, reaction and learning. The reaction level measures how participants react to an instructional program while the learning level examine the extent to which participants improve knowledge, skills, or attitudes as a result of participation. Level one evaluation has been conducted with users of the online DSG.

An online evaluation form was created to gather evaluation data from the students who played online DSG in a session of a residential IST core class which was offered in spring of 2003. DSG was also used in an online seminar on understanding systemic change in education during the summer of 2003 and evaluation questions were asked in an online discussion board. The results of evaluation will be discussed in more detail later in this paper.

Challenges and Solutions

There were several design and technical issues that the design team had to resolve to convert the paper-based game into an online version. These challenges and the solutions that the design team came up with are discussed below.

Screen Real Estate and Technological Constraints of Users

Our first challenge involved converting the paper-based game board to fit a computer display resolution of 800 x 600 pixels. Minimum technology requirements for the distance students at that time were a 56.6 Kbps modem internet connection, a sound card, and a computer display of 800 x 600 pixels. The paper version involved a lengthy instruction packet, a large game board, information and feedback cards, and forms for logging moves and recording points. We took several steps to reduce this to fit on a screen which included:

- Subsetting the game into three main Web pages: "Game Rules," "Play Game," and "Game Log," and including three tabs at the top of the interface so users can easily tab back and forth between these sections as needed.
- Aggressively editing the instructions and linking to non-critical information in pop-up windows.
- Linking to three diagrams used by players during game play in pop-up windows so that users can reference them easily without taking up screen real estate.
- Formatting the text in plain html (not Cascading Style Sheets). Because the game board includes a lot of text, formatting in plain html rather than CSS allows users to resize the text as needed via their browser settings.

Additionally, as the majority of our users were connecting to the Website via a dial-up modem, we had to ensure that the page sizes were small so that users could view and interact with the Website without excessive waiting. We knew that any frustration users may experience in accessing the game would have a negative impact on their learning experience. To ensure quick access, we avoided memory intensive graphics, and instead used PHP-generated HTML and static HTML as much as possible to create an attractive, easy-to-use, dynamically changing interface. We also streamlined and modularized our code so that pages would process as quickly as possible.

Interactivity: Single vs. Multi-Player Game Play

The paper-based version is played in small groups whose members work together to choose strategies. Currently the online version does not allow for multiple people to play one game together at the same time. Early in the creation of the online prototype, we discussed adding this functionality, however, the game is already very complex even without the multi-player dimension. In the end, we determined that at that time, the benefit gained by making the online game multi-player did not merit the additional development time and potential for player confusion. The possibility of adding this functionality in future releases will continue to be evaluated as it may enhance the players' learning experience significantly.

Maintenance and Generalizability

The future maintenance and implementation of the game was something we had to plan for early on. Diverse sources outside of the department at Indiana University had already expressed interest in the game. There had been discussion of a corporate version of the game as well. We also had to consider the possibility that future DSG maintenance teams may not have extensive programming experience. We wanted to ensure the game allowed

for easy maintenance and modifications to the interface, coding and feedback data.

There were several key development decisions made to achieve this end. We chose to program in PHP because it is a relatively easy-to-learn language, and because it provided us the capability to code interactive, dynamically generated Web pages. Additionally we used XML to simplify and organize the structure of the feedback pages by storing and retrieving the information in extensible document elements. It allowed for an easy means for future modification of the feedback component of the game with a simple text editor.

Record-Keeping and Data Preservation

The DSG can take several hours to complete – especially when playing it for the first time. Players need the ability to be able to stop play and then resume it at a later time, possibly at a different computer. There is also an extensive debriefing exercise conducted with the entire class after everyone has played the game, which meant players needed access to their game history so they could review and refer to it during the exercise.

To make the game non-computer-specific meant we could not use cookies in our programming because they are stored on the client machine. We needed to store data on the server instead. We opted to use XML to save user information and game play in order to stop and restart the game as needed from any location. We also designed a "Game Log" page which implemented the XML technology in order to record all of the user's chosen strategies along with the corresponding feedback and results. They could then use this log to perform the debriefing exercise and compare their strategies and outcomes with other players.

Evaluation and Implications for a Simulation on Systemic Change in Education

The online version of DSG was first introduced to distance IST students at Indiana University in summer of 2002. In addition to the distance class, DSG has been used in two other classes as well: a core residential IST class and an online seminar on systemic change in education. Questionnaires were distributed to the participants of these two classes to assess users' reactions on DSG and the results are discussed below.

Evaluation: User Reactions

Approximately 30 graduate students in IST who were enrolled in a residential core class, Evaluation & Change in the Instructional Development Process, in spring 2003. They played online DSG in one class section as an activity to introduce them to diffusion and adopt of innovations. An online questionnaire was distributed to them to assess their reactions on playing online DSG.

The questionnaire consisted of 10 question items, which include the respondents' demographic information, the results of their game play. Eleven students returned the questionnaire and all the respondents were graduate students who were enroll in an IST core class at Indiana University. In terms of their performance, a majority of the respondents succeed in achieving the goal of the game, which was to obtain more than 10 adopters in a given period of time, in one or two attempts. Question items 4 and 5 included open ended question that asked the respondents whether they felt online DSG was realistic and what strategies they used to obtain adopters. Seven participants responded that they felt the game was realistic.

The question item 6-8 asked the respondents of their reactions of playing online DSG on a 5-point Lickert scale (1=strongly disagree, 5=strongly agree). The respondents agreed or strongly agreed that playing online DSG was a worthwhile learning experience (M=4.636, SD=0.504). The respondents also agreed or strongly agreed that they would recommend online DSG to others if they want to learn about the change process for adopting an innovation (M=4.545, SD=0.522). They also responded that online DSG motivated them to learn more about the change process for adopting an innovation (M=4.636, SD=0.50). When asked what they liked best about online DSG, the participants responded that the game was interesting because it was realistic, moderately challenging, and interactive.

Another evaluation was conducted of the participants of an online seminar on systemic change in education that was offered to in-service teachers in the summer of 2003. These participants played online DSG as an introductory activity to learn the topic of systemic change. After playing the game individually, they posted their reflections on their game play in an online discussion forum. 17 messages were posted on the discussion forum regarding their general reactions on the game play and whether they felt the game was realistic. In general, they exhibited positive responses on their experience playing this game. One participant stated:

> *First of all I would like to note how much FUN it was to play this game! My second immediate thought was what a great pedagogic tool for the classroom. You have to read, problem solve and think critically,*

many of the assets we want from our students in today's society. Too bad more simulation games like this aren't used in the classroom. I think students would find it fascinating, interesting and beneficial.

Many participants also reported that the game was realistic. For instance, one participant stated:

I definitely think that it gives the participant a very realistic simulation of how innovations are adopted in a school system. First, I note the different roles and personalities within the organization and the complexity that lies therin.

This simulation definitely highlights the importance of knowing who's who before you spend a lot of time on different diffusion activities. Position matters, but so does personality and social influence outside of one's formal role at work. I also thought that the two year timeframe was quite instructive. When you begin the game it feels like you have so much time that hitting your goal will be no problem but soon you realize how long it takes to win over adopters.

Change agents really need to have a reasonable long-term plan for implementing their innovations. Overall I found the simulation quite interesting and stimulating. It makes me think about my own school building and how I can introduce new ideas there.

Such positive responses from the users on the reality of DSG illustrates the possibilities to use Web-based simulation to teach the concept of systemic change in education, which will be discussed below.

Implications for Design of an Educational Systems Simulation on the Web: *SimEd*

DSG has demonstrated the potential for creating a simulation that provides interactive and prompt feedback to a player by taking advantage of current Web technologies. Based upon the experience of developing and implementing DSG, the first author expects to develop over the next several years a prototype simulation for designing educational systems that will run on the Web. He is calling this simulation, *SimEd*.

SimEd is envisioned to be something like *SimCity*, except that it will allow teachers, administrators, parents, students and school board members to design educational systems, not cities. As they design different variations of educational systems, they will see how a given design succeeds or fails over time. That is, they will be able to experience temporally the consequences of their design decisions, and they will be able to adjust their designs as their educational systems evolve. Thus, *SimEd* is expected to be a set of visioning tools. As an analogy, architects have created computer tools that allow them to create virtual buildings. These tools are very useful to envision what a particular design will be like, how it does or does not meet client needs, and to modify designs before committing to actual construction. Clients are able to virtually "walk" through such buildings before they are built, in contrast to looking at miniature models constructed out of balsa wood.

SimEd will help make more concrete some rather abstract and difficult-to-understand educational systems properties. But these properties are not those of physical buildings or cities. Rather, they will be based on the SIGGS Theory Model (Frick, 2002). The SIGGS Web site is merely descriptive of these educational systems properties. It does not allow people to experience them in a way such as *SimCity* provides an experience of designing a city and observing the long-term consequences. *SimEd* will use systems theory as a basis for the rules that drive the simulation through a period of compressed time – in particular, the educational systems theory proposed by Maccia and Maccia (1966). See http://education.indiana.edu/~frick/edutheo.html .

SimEd will utilize a combination of Web technologies. The computer interface will run on a user's Web browser using a plug-in for *Flash MX*. *Flash MX* will allow animation, drag-and-drop interaction, and playing of "movies" that are controlled by ActionScript, a Flash programming language. The Flash interface will interact with Web server programs written in PHP, a widely used programming language for Web applications. PHP scripts in turn will store system states and user data in XML files on the server. This strategy will allow SimEd to run on virtually any Web server and with any computer Web browser with the Flash plug-in installed (a free and fast download from Macromedia). The Diffusion Simulation presented in this paper is written in PHP and uses XML data storage. It does not use Flash MX, as MX was not available at the time. However, to get an idea of how these technologies can interact, see a drag-and-drop activity with feedback at: http://mentor.ucs.indiana.edu/~r641011/flashdemo/dragdrop.html . Indeed, the R641 class in spring 2003 demonstrated proof of concept that these technologies can work together successfully. See: http://www.indiana.edu/~tedfrick/r641/.

The *No Child Left Behind Act* of 2001 is likely to fuel the need for systemic change in education. *SimEd* is expected to help teachers, students, parents, administrators and school boards to: 1) understand

the nature of systemic change in education; and 2) know what to look for in terms of consequences of new educational system designs.

References

Boling, E., & Frick, T. W. (1997). Holistic rapid prototyping for Web design: Early usability testing is essential. In B. Khan (Ed.), *Web-based instruction* (pp.319-328). Englewood Cliffs, NJ: Educational Technology Publications.

Frick, T. W. (2002). *Educational systems theory*. Retrieved September 29, 2003, from http://education.indiana.edu/~frick/siggs.html

Frick, T. W., & Boling, E. (2002). *Effective Web instruction: Handbook for an inquiry-based process*. Book in progress on the Web.

Kirkpatrick, D. (1994). *Evaluating Training Programs*. San Francisco, CA: Berrett-Koehler Publishers.

Maccia, E. S., & Maccia, G. S. (1966). *Development of educational theory derived from three theory models.* Washington, DC: U.S. Office of Education, Project No. 5-0638.

Molenda, M., & Rice, J. A. (1979). The diffusion simulation game. *Simulation and Games, 10*(4), 459-467.

Rubin, J. (1994). Handbook of usability testing: How to plan, design, and conduct effective tests. New York: Wiley.