DESIGN THEORY FOR INSTRUCTIONAL OVERLAYS

WITHIN COMPLEX SIMULATION GAMES

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ABSTRACT

Simulation games can be valuable tools for students to learn through experience. Compared with real-world experience, instructional simulation games can decrease student time to learn. Players can also experience failure without suffering real-world consequences. However, without additional instructional support, attempts to learn *complex* knowledge and skills through simulation games can be so challenging that frustrated students disengage and never succeed. When instructional support is provided before, during or after a learning episode in a simulation, this is called an *instructional overlay* (IO). No design theory for instructional overlays (DTIO) existed prior to this study.

Formative research methods were used to develop a DTIO. Fifteen participants were observed while individually playing an online version of the Diffusion Simulation Game (DSG). The DSG requires players, acting as change agents, to encourage fictional teachers at a fictional school to adopt an innovation. To succeed in the DSG, players must appropriately apply principles from Diffusion of Innovations theory. IOs were provided during play. Screencasts of gameplay were recorded digitally, including audio of player verbal think-aloud.

Results indicated player learning problems which included: uncertainty about when and how to use supportive information in an IO; failure to select appropriate diffusion of innovation (DoI) strategies; focus on winning instead of understanding DoI principles; unwillingness to abandon incorrect beliefs about DoI; lack of proficiency in discovering regularities or patterns through gameplay; and cognitive overload. Based on these findings, guidelines for DTIO within instructional simulation games were created for *building game strategies, conducting game experiments, interpreting game data*, and *regulating game-based learning* processes.

Introduction

Technology-based games and simulations have "…quickly become one of the most pervasive, profitable, and influential forms of entertainment in the United States and across the world" (Squire, 2003, p. 2). Although a majority of students enjoy playing games, and simulation games can teach knowledge and competence with regard to dealing with complex domains of reality (Leutner, 2002), there remains skepticism among educators and researchers about the effectiveness and efficiency of using games for instructional purposes (Clark, 2007) . In addition to Squire's (2003) observation that there are "…tremendous advancements in gaming technology that have not been explored within the instructional technology community" (p. 4), de Jong and van Joolingen (1998) have also reported that without appropriate instructional support, learning problems may occur during gameplay, such as acquiring misconceptions and incomplete or disorganized knowledge.

Problem Statement

The authors became interested in characteristics of problems that keep learners from performing successfully in complex simulation games. What instructional methods might help address the above challenges and positively influence the learning and gameplay outcomes? A review of extant literature showed that no design theory for instructional overlays (DTIO) currently existed for educational games with complex learning objectives. In order to address this gap, we sought to develop a DTIO for complex simulation games. This theory should describe potential problems that learners may encounter in complex simulation games and discuss how IOs can them overcome these problems.

Instructional Overlays (IOs)

Definition of an Instructional Overlay

According to Reigeluth and Myers (2012), an instructional overlay (IO) is defined as any feature that provides learners with instructional support to optimize learning and motivation before, during or after a learning episode in a simulation, so as to provide just-in-time learning within a motivational context. The IO is built into the game, minimizing or eliminating the need for a trainer. Imagine a feature that allows students to "freeze time" when they encounter a learning gap that they need to fill in order to proceed with the simulation. A virtual mentor could appear and provide customized tutoring to develop a particular skill or provide additional knowledge. Reigeluth and Myers call this "frozen time" an "instructional space," which is a synonym for an IO.

Upon reaching a standard of mastery of knowledge or skills, a student would return to the simulation game context, and time would be "unfrozen". S/he could then apply what has just been learned and continue playing until a further challenge/learning gap is encountered. This learning-doing cycle is constantly repeated throughout gameplay.

Types of IOs

According to Reigeluth and Myers (2012), three major types of IOs exist: *adjusting*, *coaching*, and *instructing*. Adjusting is the least intrusive type of instructional support because "it occurs 'behind the scenes', leaving a player unaware that any instructional support has been provided" (p. 27), hence maximizing a player's flow state (Csikszentmihalyi, 1990). Adjusting should be used when "a task is difficult for a player to learn to do without support". While adjusting is the least intrusive method among the IOs, it may require time and creative skills necessary for designers and developers to modify a game, as well as considerable time needed by software engineers to create and debug the programming code to implement the adjustment.

In contrast, coaching and instructing do not necessarily involve revising game mechanics and other aspects behind the scenes. Coaching can be done by simply providing tips, examples or demonstrations of a skill. Coaching assumes the form of supportive information or just-in-time (JIT) information provided by a virtual mentor before, during or after a learning episode in a game.

Instructing is used when more intrusive and extensive intervention is needed to support more difficult tasks or learners who are struggling a great deal with the game. Examples of instructing might be part-task practice (see van Merriënboer, Clark, & de Croock, 2002) or use of a virtual mentor. Instructing is usually conducted by freezing a game so that learners can focus on instruction being given, or it can be done before playing a game or between games.

Conceptual Framework for Complex Simulation Games

Simulation games in education can be traced back to the 1600s (Gredler, 2004; Myers, 2012; Smith, 2010). Over the past several decades, use of simulation games for instructional purposes have become more popular due to the proliferation of relatively inexpensive computer technologies. Computers have enabled imaginative, interactive, and highly motivational instructional environments that can support learning in complex domains of reality (Leutner, 2002). In order to improve use of simulation games for instructional purposes, it is important to first understand the basic characteristics of simulation games.

Simulation Games

According to Heinich, Molenda, Russell and Smaldino (2002), “a simulation game combines the attributes of a simulation (role playing, a model of reality) with the attributes of a game (striving towards a goal, specific rules)" (p. 35). Because simulation games combine characteristics of both, "they provide conditions for *holistic learning.* That is, through the modeling of reality and through the players' interactions as they strive to succeed, learners *encounter a whole and dynamic view of the process they are studying*" (Heinich, et al., 2002, p. 35).

Leemkuil, de Jong and Ootes (2000) identified four relevant characteristics of simulation games. First, a simulation game should *reach a goal*. This goal should either be to reach the highest level of proficiency and/or efficiency at solving a particular problem or a series of problems, or be the best among competitors. Since there are different forms of goals, there are also different ways in which goals of a game can serve a cognitive function. Hays and Singer (1989) gave an overview of the ways in which games can be used to train cognitive skills:

> … *in* training to: assess entry level behavior; measure criterion performance; aid in formative and summative evaluations; provide instruction in specific knowledge and skills; and to teach attitudes. Games can be used *before* traditional instruction to provide advanced organizational information to trainees so that they are better prepared for traditional instruction. Games can be used *in place of* traditional instruction to transmit facts, teach skills, and provide insights. Games can also be used interspersed with or *after* traditional instruction for drill and practice, to integrate and maintain skills, or to illustrate the dynamics or abstract principles of a task… (p. 194).

The second characteristic of games is *constraints*, which include time (or resource) limits, if-then conditions, rules and incentives. In most cases, when resources and incentives are used in games, a trade-off is involved. For example, every action that a person takes uses some resources, and resources are limited. So the question faced by the player is, "When should I use my resources?" In certain cases, the player will have to take risks to accomplish his intermediate or final goals.

The third characteristic is *the sense of winning or losing* that is gained by competing with a system, other people or oneself (i.e., outperforming one's previous performance). Lastly, the *situatedness* of games is an important characteristic. Games are situated in a specific context that makes them (more or less) realistic, appealing and motivating for the players. Some important elements related to the situatedness of games are: validity/fidelity, complexity, risk, uncertainty, surprise, unexpected events, role playing, access to information and the representation form of the game. Since the introduction of computer-based games, realism and complexity have received new attention because computers introduced new possibilities in regard to ways to simulate complex processes in a short time for a relatively low cost (Leemkuil, de Jong, & Ootes, 2000).

Furthermore, developments in computer technology have created ways through which games can be given a high degree of realism. However, a caveat of implementing complex models in games is that they may become unplayable; therefore it is important to create a balance between a game’s complexity and its manageability. If it is too simple or too complex, a learner may not learn anything and may not be fully engaged. According to MacCallum and Stewart (1981), the complexity measure is often accompanied by some degree of recognition of the following indicators:

- quantity of information included in the game exercise, which may be indicated by the volume of the players’ notes or amount of the instructional aid's input;
- number of variables represented to the players and whether complexity increases as the game progresses;
- number of possible strategies that participants may adopt and the extent to which they are enumerated by the presenter;
- mathematical complexity of the model and whether this can be varied on different occasions of play; and
- number of actions required of the participants. This is indicated by the number of decisions to be made in the model-based games, but varies with the actions of the participants in most situation-based games. (p.14)

Instructional Simulation Games

An instructional simulation game contains three major aspects of design that help it to achieve an instructional goal (Reigeluth & Schwartz, 1989): a *scenario*, which mimics a real life situation, including objects, persons and places; a *model*, represented by the rules and mechanics of user interaction with a simulated environment; and an *instructional overlay*, represented by strategies used to optimize learning and motivation. A scenario and underlying model should reflect, to some degree, the situation being simulated. Having maximum fidelity is expected to increase learner ability to transfer what has been learned into a real situation. However, Reigeluth and Schwartz caution that details and complexities of real situations may also provide too many stimuli for learners to be able to acquire the desired content and, therefore, may result in cognitive overload. Glaser, Schauble, Raghavan and Zeitz (1992) also addressed this problem of learners who encountered too many variables and then eventually could not draw any conclusions.

Complex Learning

Complex learning aims at learning how to complete authentic tasks that require the use, coordination, and integration of knowledge, skills, and attitudes (van Merriënboer, Kirschner, & Kester, 2003). It also includes ability to transfer knowledge and skills learned in an instructional intervention into daily life or a work setting (Kirschner & van Merriënboer, 2009).

Van Merriënboer, Clark, & de Croock (2002) state that the way in which novices master complex tasks is quite different than the way they master simple tasks; moreover, they affirm that a complex set of interrelated tasks cannot be effectively mastered by simply sequencing a series of simplified learning tasks. Complex learning goes beyond learning simple separate skills in isolation. In contrast to simple tasks, complex tasks have a great variety of solutions, cannot be mastered in a single session, and exert a very high cognitive load on the learner (van Merriënboer, Kester, & Paas, 2006). Complex learning is “foremost dealing with learning to coordinate and integrate the separate skills that constitute real-life task performance. Thus, in complex learning the whole is clearly more than the sum of its parts because it also includes the ability to coordinate and integrate those parts.” (van Merriënboer, Clark, & de Croock, 2002, p. 40).

Being able to master the skills to effectively spread an innovation within an organization or community is a process that requires complex learning because there is no a one-size fits all solution. In order for an individual to diffuse an innovation successfully, he must be able to coordinate and integrate several constituent skills such as identifying peoples’ adopter types based on their personal characteristics; detecting and utilizing social networks; and identifying opinion leaders. If he only acknowledges the interest level of the people in the organization, but does not consider their personal characteristics, then his efforts might be wasted. Likewise, if he has knowledge of the characteristics of the people he is trying to persuade, but does not know their social relationships, he may have to put more time and effort than expected.

Failure of Initial Attempts to Create a DTIO for Complex Simulation Games

The first author proposed and experimented with various instructional overlay methods and examined their effects in terms of learning and motivation within the Diffusion Simulation Game (DSG). See Appendix A for more information about the DSG. After conducting several small case studies with various IO methods within the DSG, the difficulty of finding one most effective IO method became obvious. Potential learning problems that might have caused the learners to fail within the DSG were identified. She reasoned that, if an accurate account of specific reasons that prevented learners from acquiring skills necessary to succeed in the DSG were found, then it would be easier to discover the most appropriate IO methods and, thus, learners would perform better.

According to Reigeluth and Carr-Chellman (2009), determining the most useful instructional methods according to each specific problematic situation is part of the process by which a design theory is built. These are referred to as *situational methods of instruction,* in contrast with *universal methods of instruction*.

Method

Guiding research questions in the present study were:

1. What characteristic game behaviors are observed when participants play a complex simulation game?
2. What *learning problems* might cause these characteristic game behaviors?
3. Were the *IO methods* provided effective in solving these learning problems?
4. For those learners for whom the provided IO methods did not work, what alternative IO methods might be recommended?

In order to answer these questions, the formative research method developed by Reigeluth and Frick (1999) was adopted. Formative research, as a means to improve an existing instructional design theory or for developing a new grounded theory, entails asking such guiding questions as “What methods worked well?” “What did not work well?” and “How can it be improved?” The method uses a case study approach and can be used for both designed and naturalistic cases, which instantiate (as closely as possible) an instructional design theory. The process of conducting formative research involves: (1) selecting or creating an instructional design theory to improve; (2) designing an instance of the theory; (3) collecting and analyzing formative data on the instance; (4) revising the instance; (5) repeating the data collection and revision cycle; and (6) offering tentative revisions for the theory.

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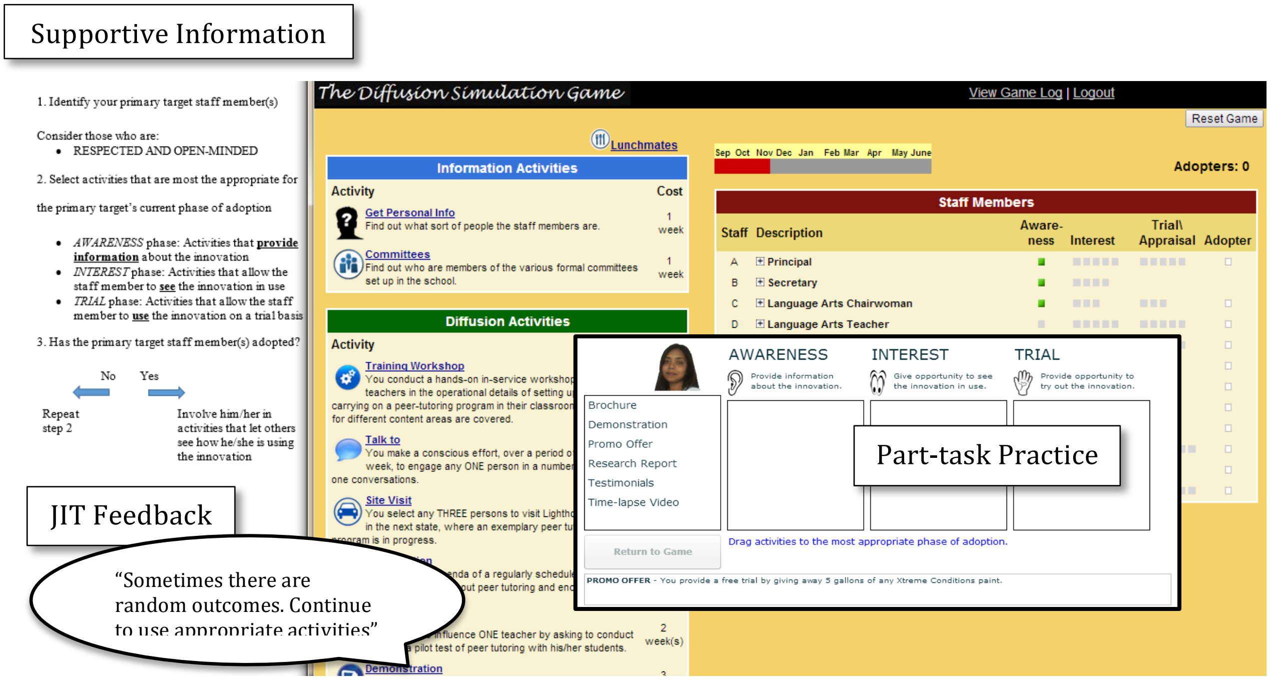
1. Selecting or creating an instructional design theory

A tentative version of a design theory for instructional overlays (DTIO) for complex simulations games was created, based largely on previous work done by Reigeluth and Schwartz (1989), de Jong and van Joolingen (1998), Merrill (2002; 2013), and van Merriënboer, Clark, and de Croock's 4C/ID model (2002). The *tentative* DTIO was also influenced by several learning problems identified in earlier studies of the DSG (Kwon, Lara, Enfield, & Frick, 2013).

2. Designing an instance of the theory

An IO instance that includes elements of the tentative DTIO was designed to accompany the Diffusion Simulation Game. See Figure 1. The reason for designing the IO instance was to seek insight into when and how to provide IOs for complex game-based learning (GBL) processes and incorporate those ideas into the creation of a DTIO.

Supportive information (van Merriënboer & Kirschner, 2007) was provided alongside the DSG interface, as can be partially seen in Figure 1. Just-in-time (JIT) feedback was verbally provided as needed by one of the researchers, depending on types of misconceptions inferred from observing DSG gameplay. These scripted feedback messages were meant to simulate what a virtual agent might say to a player during a game when certain patterns of errors are observed. We did it this way to save time and effort required to modify DSG code in order to actually create such a virtual agent, since we were in early stages of DTIO development. Part-task practice, in Figure 1 was displayed after pausing a game and until practice items were correctly answered.



Figure

1. Design instance for the *tentative* DTIO

3. Collecting and Analyzing Formative Data on the Instance

Seven participants who had no knowledge of DoI theory and who had not played the DSG were observed and interviewed during the *first* round of data collection, which led to development of a tentative version of the DTIO. Players initially completed a short background survey, took a pre-test on knowledge of DoI concepts and appropriate application of DoI principles, played the DSG twice, took an identical post-test, and participated in an exit interview. During gameplay, players were also asked to rate each IO in terms of helpfulness using a Likert scale from 1 to 5 to which they were exposed.

3.1. Gameplay. Gameplay included two game sessions. The first game session was simply used to familiarize the players with the game interface, mechanics and rules. This session lasted ten minutes. The second game session was the focus of the study during which players were asked to think-aloud and were notified that a researcher would interrupt them to inquire about their learning problems and offer coaching and instructing. This game session typically lasted about an hour.

In order to answer our research questions, we collected and analyzed descriptive and formative game data:

- MySQL game-play data (see Figure 2),
- Screen recording of game-plays,
- Video/audio transcripts of think-aloud done by players as well as player reactions to IOs provided.

recordId	username	gameId	activityId	activity	cost	weeksElapsed	feedbackId	adopters	staff	latestPoints	latestAdopters	adoptionPoints	timestamp
9930		1	0	Get Personal Info	1	1	51	0	G,			0	2013-05-18 11:18:15
9931		2	0	Get Personal Info	1	1	51	0	A,			0	2013-05-18 11:42:29
9932		2	1	Lunchmates	1	2	52	0				0	2013-05-18 11:43:33
9933		2	2	Committees	1	3	53	0				0	2013-05-18 11:45:14
9934		2	4	Talk to	0	3	1	0	H,			0	2013-05-18 11:46:30
9935		2	9	Blog Post in JHS web	1	4	37_2	0		A:1,C:1,D:1,F:1,H:1,I:1,K:1,		0.8	2013-05-18 11:47:16
9936		2	6	Presentation	2	6	25_1	0		B:1,G:1,		1.2	2013-05-18 11:48:28
9937		2	4	Talk to	0	6	1	0	E,			1.2	2013-05-18 11:51:47
9938		2	0	Get Personal Info	1	7	51	0	E,			1.2	2013-05-18 11:52:19
9939		2	0	Get Personal Info	1	8	51	0	J,			1.2	2013-05-18 11:52:57
9940		2	0	Get Personal Info	1	9	51	0	L,			1.2	2013-05-18 11:53:18

Figure 2. Screen capture of DSG MySQL database: sample log of turns played.

3.2. Learning test. The same test was administered before and after gameplay in order to calculate gains in learning. The test used a context similar to the DSG, but brief descriptions of each *teacher* and a list of *activities* were different from those in the DSG. The test was designed to measure *transfer* of conceptual and procedural knowledge related to DoI theory, including stages of adoption, adopter types, and selection of specific diffusion activities appropriate for various stages of teacher adoption and adopter types.

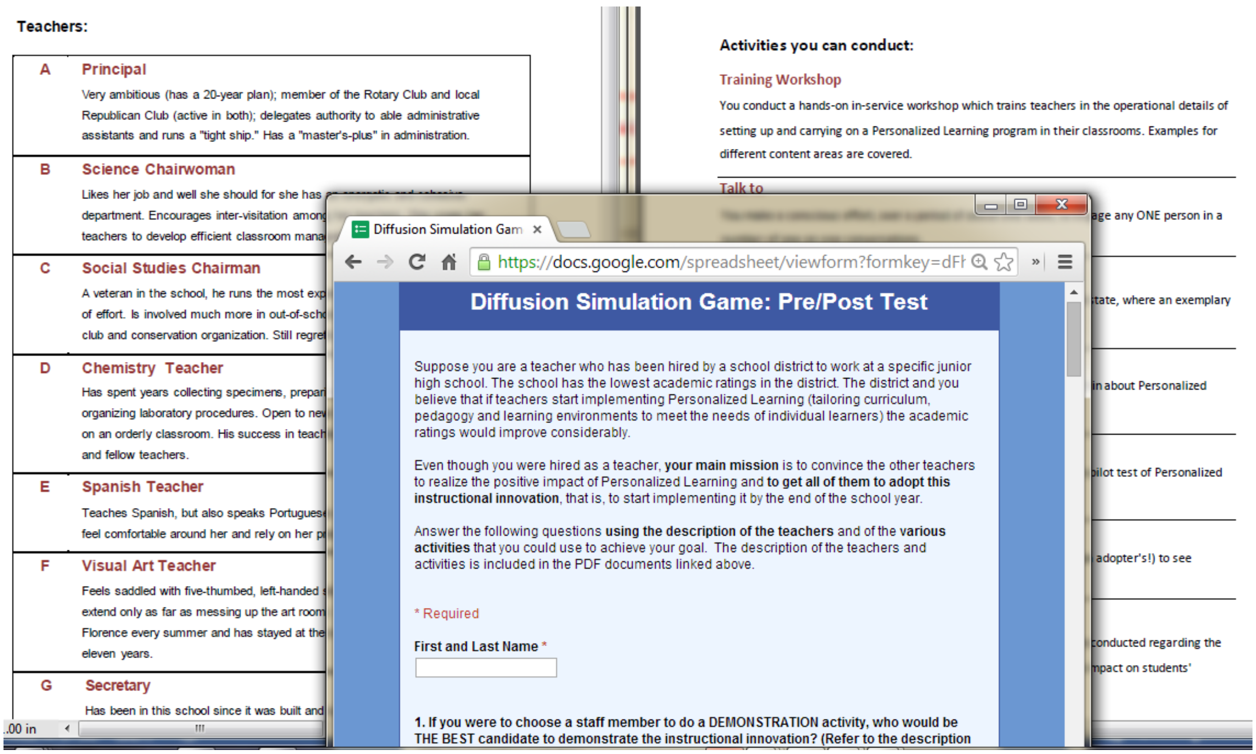


Figure 2. Screenshot of the learning test

3.3. Semi-structured post-interview. Some of the post-game interview questions included “On a scale of 1 to 5, what were your preferences toward each of the instructional supports?”, “Why did you like it and what did you like about it?”, and “Which instructional supports should stay, be removed or be improved?” In particular, the first question above (Likert scale) was prompted either during a game, right after IO methods appeared, or after a game during a post-interview session. This question is referred to, hereafter, as the IO preference survey.

4. Revising the instance

While the goal of the first round of data collection and analysis was to develop a new *tentative* theory, the second round was to test and improve this theory. Minor modifications to the design instance occurred upon completion of the first round of data collection and analysis, which included timing and change of delivery format of JIT feedback from online interactions to face-to-face. The rationale of the modification was to ensure that the design instance helped us to capture as many potential learning problems as accurately as possible.

5. Repeating the data collection and revision cycle

The same procedures described above were followed in the second round of data collection with eight new participants who had no prior knowledge of DoI theory and who had never played the DSG.

6. Offering tentative revisions for the theory

Based on the preceding steps of formative research, the result is a revised DTIO that is grounded upon empirical findings from the data collection and revision process. These revisions are described next.

Results

Results from two rounds of data collection and revision of the DTIO and its respective design instances indicated student learning problems that included: uncertainty about when and how to use supportive information in the IO, incomplete or incorrect application of DoI principles that the DSG was designed to teach, focus on winning the game instead of understanding DoI principles, student unwillingness to abandon incorrect beliefs about DoI, lack of proficiency in finding regularities or patterns through gameplay, and cognitive overload.

Design guidelines that addressed each discovered learning problem were laid out according to game-based learning (GBL) processes. Based on a review of literature on the topic of games, simulation, and scientific inquiry (de Jong & van Joolingen, 1998; Friedler, Nachmias, & Linn, 1990; Rivers & Vockell, 1987), we have theorized that successful game-based learning is related to the following processes: *building game strategies, conducting game experiments, interpreting game data,* and *regulation of game-based learning*. These processes are based on what has been called theories of scientific discovery learning (Klahr & Dunbar, 1988; Reimann, 1991). Rivers and Vockell (1987), for example, described a cycle that involves planning (designing an experiment), executing (carrying out the experiment and collecting data), and evaluating (analyzing data and developing a hypothesis).

The revised DTIO for complex simulations and games is presented in Table 1. Space does not permit inclusion of case studies of individual gameplay that led to identification of learning problems and IO methods that constitute the DTIO theory.

Table 1.

Design Theory for Instructional Overlays for Complex Simulation Games

GBL Process	**Encountered Learning Problems (P)**	**Proposed IO Methods (M)**	**Signal Timing**
1. *Building game strategies*		M-1. Display supportive information.	Display throughout the game.
	P-1.1. Learners are unable to state game strategies on the basis of game experiences.	M-1.1. Provide supportive information for learner planning.	
	P-1.2. Learners fail to recall or retain important information.	M-1.2. Keep supportive information visible to learners at all times during gameplay.	
	P-1.3. Learners are vague about when and how to use supportive information.	M-1.3. Indicate when and where parts of supportive information should be applied to the simulation game (e.g., provide a decision aid for sequencing theoretical principles in supportive information).	
2. *Carrying out Game Experiments*		M-2. Prompt with JIT feedback.	Prompt during gameplay.
	P-2.1. Learners form misconceptions resulting from idiosyncratic game outcomes (e.g., due to chance).	M-2.1. Provide some cue that the action was appropriate despite a negative outcome or was inappropriate despite a positive outcome (e.g., *"Do not let this deter you. Continue to use appropriate activities."*).	
	P-2.2. Learners incompletely apply theoretical principles that the simulation game is designed to teach, which are provided in the supportive information.	M-2.2. Cue learners to what is missing (e.g., *"Pay attention to whether the staff member is **both** respected and open-minded, according to Personal Information."*).	

Table 1 (Continued)

	P-2.3. Learners focus on winning vs. understanding (i.e., focus on simulation game elements instead of trying to understand the more general principles that the simulation game is designed to teach, which are provided in the supportive information).	M-2.3. Remind learners or reinforce learner use of general principles that the simulation game is designed to teach, which are provided in supportive information (e.g., *"Read the supportive information carefully. Focus on staff members who are respected and open-minded first to get them to become adopters, and then use these adopters to influence others."*).	
	P-2.4. Learners appear to be biased (i.e., unwilling to change current thinking).	M-2.4. Help learners recognize game outcomes that are in opposition to incorrect, ineffective ideas that they are holding onto.	
3. *Interpreting game data*	P-3. Learners lack proficiency in finding regularities or patterns.	M-3. Pause the game to conduct part-task practice.	Pause the game until the part-task practice is mastered.
	P-3.1. Learners appear to suffer from *extraneous* cognitive load (e.g., *split-attention effect*).	M-3.1. Incorporate part-task practice using a scenario identical to that in the game.	
4. *Regulation of GBL*	P-4.1. Learners appear to suffer from *intrinsic* cognitive overload.	M-4.1. Consider changing the simulation game to make it less complex, or create a series of games that proceed from least to most complex.	Redesign the game.
5. *Instructing*	P-5. Not observed, because it was excluded from this study.	M-5. Explicitly teach game content knowledge. See discussion below.	Do before gameplay.
6. *Debriefing*	P-6. Not observed, because it was excluded from this study.	M-6. Debrief players. See discussion below.	Do after gameplay.

Discussion

Formative Research for Developing Instructional Design Theory

Formative research is a form of design research (Reigeluth & An, 2009; Reigeluth & Frick, 1999). The goal of research should be to create knowledge (Steiner, 1988). To design something is to create a plan for it. Thus, the goal of research *on* instructional design should be to create knowledge about instructional design—knowledge about how to devise plans for instruction. This knowledge of instructional design takes the form of prescriptions or guidelines consisting of signs for how to devise plans for instruction (see Peirce, 1932).

The present research study has resulted in guidelines on how to devise plans for creating IOs for complex simulation games. Those prescriptions are included in Table 1. However, these guidelines are not knowledge; rather they are praxiological theory. "Theory when it meets certain standards is knowledge" (Steiner, 1988, pp. 4-5). Hence, what is in Table 1 is IO design *theory*, not instructional design knowledge, since further empirical validation studies are needed to test and improve this IO design theory.

Design Theory for Instructional Overlays (DTIOs) for Complex Simulation Games

Methods of the DTIO we have developed are listed in column M in Table 1. These are general prescriptions intended for instructional designers who attempt to create IOs for complex simulation games. Each of the methods is discussed briefly below, tying it to prior research and results from the present study.

M-1.1. Provide supportive information for learner planning.

De Jong and van Joolingen (1998) and Njoo and de Jong (1993) addressed the situation in which learners were not able to state or adapt hypotheses on the basis of data gathered. After accessing *staff member information* in the DSG in our study, players asked how to utilize staff member information for building game strategies. Additionally, they had no clear conception of how *diffusion activities* were conditionally dependent on *stages of adoption* and on adopter types implied in *staff member information*. That is, they were unable to form if-then rules that included adopter types, stages of adoption, and diffusion strategies.

To support this learning problem, the following IO method was implemented in the DSG: As soon as players began interacting with a game, a small panel appeared adjacent to the game space. In the small panel, supportive information appeared. See Figure 4. According to van Merriënboer, Clark and de Croock (2002), this is information

> that is supportive to the learning and the performance of non-recurrent aspects of the learning tasks. It provides a bridge between the learners' prior knowledge and the learning tasks and consists of mental models, cognitive strategies and cognitive feedback. It should be always available to the learners (p. 44).

Supportive information for learner planning may, as Charney, Reder, and Kusbit (1990) have postulated, be especially helpful for learners who have low prior knowledge. Providing supportive information for learner planning takes away decisions from learners and in this way helps them manage the learning process. There are two available forms of how the support can be given. If a learner is not required to "figure out" the generality and receives the information in example form with the generality(ies) provided, then the form is called the expository approach to supportive information for learner planning. If an example is presented and a learner is required to figure out the generality, then it is called the discovery approach (Reigeluth & Schwartz, 1989). In this study, the expository approach to supportive information for learner planning was implemented.

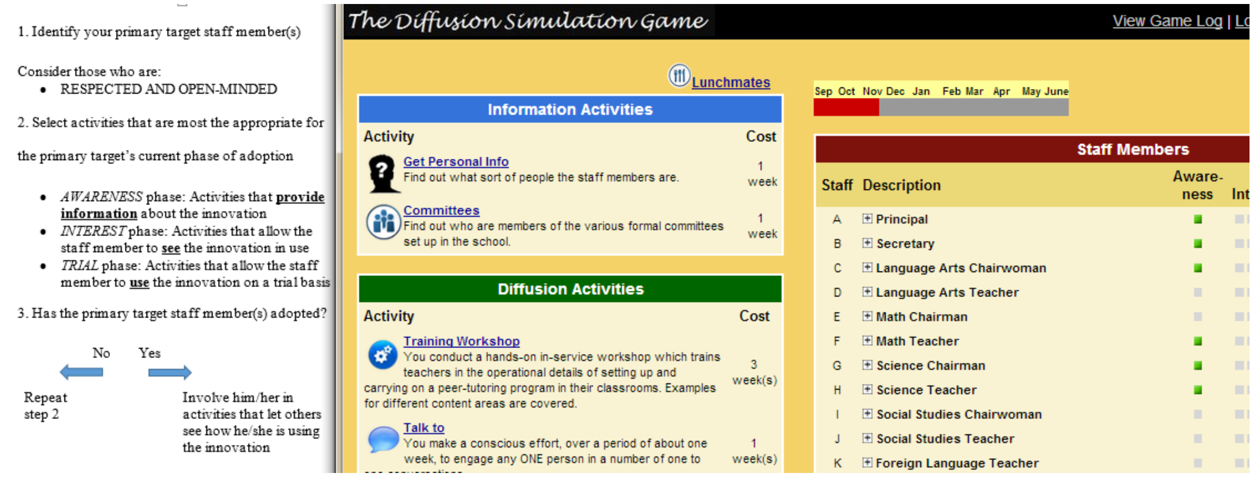


Figure 4. Supportive information panel located to the left of the game

M-1.2. Keep supportive information visible to learners at all times during gameplay.

Another problem that players experienced was failure to recall a hint that was provided earlier via supportive information in the game. Observation data in the Kwon, Lara, Enfield and Frick (2013) study showed that even though subjects received hints from an agent earlier in gameplay, as a game progressed further, the more players tended to use strategies that were inconsistent with these hints. During post-interviews, players revealed that they failed to recall the hints that were previously provided.

In the present study, a solution was to display supportive information panel *throughout* the game. A further reason to keep supportive information visible is to reduce cognitive load (see van Merriënboer, Kirschner & Kester, 2003).

M-1.3. Indicate *when* and *where* parts of the supportive information should be applied.

Most players apparently did not understand that DoI activities should be selected conditionally—depending on specific game circumstances. For example, player 6 was not certain as to *when* to carry out the goals indicated in the supportive information, and then appeared to ignore the information. According to his response, the supportive information may have been too *ambiguous* and not concrete enough. He said "It's just kind of *general* at this point for me." The ambiguity of the supportive information could be one of the reasons why this player did not try the advised strategy provided in the supportive information. Therefore, we propose to include a decision aid next to important goal(s) in supportive information. See Figure 5 for an example. Such cues would allow players to focus on and accomplish important goals *at appropriate times*.

3. Persuade the primary target (s) to adopt the innovation early **(first 15-20 weeks)** in the game.

Figure 5. Decision aid added to a goal in the supportive information

M-2.1. Prompt with just-in-time (JIT) feedback. Provide some cue that the action was appropriate despite a negative outcome.

Even with supportive information present, some players still experienced misconceptions during gameplay. Prior studies related to the DSG (Enfield, 2012; Enfield, Myers, Lara, & Frick, 2011) revealed that the stochastic nature of the game could lead learners to misconceptions. In an attempt to model what happens in real life, appropriate activities were sometimes ineffective in the DSG. We observed that when an activity did not work the first time it was tried, most players were too quick to jump to a conclusion—a wrong conclusion, as it turned out.

In order to address this issue, relevant task-specific information was provided to a player the first time that he or she used an appropriate activity without an effective outcome. JIT feedback described the stochastic nature of the game phenomenon and encouraged players by saying, "Sometimes there are random outcomes, although your strategies are appropriate."

M-2.2. Cue learners to what is missing.

Sometimes players made inappropriate moves in the DSG because they did not use the whole range of instructions noted in the supportive information, what we call *incomplete* experimentation behavior. For example, some players only considered one aspect (e.g., open-mindedness) of the characteristics of a teacher targeted in a diffusion activity when *both* aspects (e.g., being respected and being open-minded) should have been considered. Consequently, diffusion activities were repeatedly applied to inappropriate staff members. Thus, players who evidenced this problem were cued (JIT) to what was missing by being told, “Pay attention to whether the staff member is *both* respected and open-minded, according to *Personal Information*.”

M-2.3. Remind learners or reinforce learners’ use of general principles that the simulation game is designed to teach, which are provided in supportive information.

The learning problem alluded to here is what van Joolingen et al., (2005) call the *engineering approach*, which occurs when learners attempt to create a desirable outcome instead of trying to understand the underlying mental model. For example, player 5 did not try to understand the mental model specified in the supportive information. Instead of trying to create game experiments that provided insights into this model, she carried out experiments that were *safe* to her (de Jong & van Joolingen, 1998) and focused on *winning*. She said: “I'm really safe… I don't want to leave any open-ends with them, if that makes sense... I want to win with... as little failure as possible.”

JIT feedback was provided to remind and reinforce players to use general principles of DoI theory presented in supportive information: “Read supportive information carefully. Focus on staff members who are *respected* and *open-minded*—first to get them to become *adopters*, and then use these adopters to influence others." After being provided with JIT feedback, players who used the *engineering approach* no longer exhibited this learning problem.

M-2.4. Help learners recognize game outcomes that are in opposition to incorrect, ineffective ideas that they are holding onto..

Especially noteworthy in this study was that player *bias* appeared to be an obstacle for several participants. They apparently believed that someone who was in a leadership position would also be an opinion leader. This bias was an apparent unwillingness to change beliefs about diffusion strategies that were inconsistent with DoI theory. Even when faced with DSG game outcomes that contradicted those beliefs, those players appeared to be unwilling to change those beliefs.

One of the ways to address *bias*, according to Chinn and Brewer (1993), is to try to emphasize *credibility* of simulation game outcomes. Among ways to enhance credibility of simulation game outcomes, one strategy is to encourage players to experiment and observe results of what works and what does not. If players are encouraged to directly compare results of their poorly selected diffusion strategies with outcomes of a recommended strategy that is more effective and efficient, they might pursue that recommended strategy in order to be more successful in the simulation game. See following dialogue.

> *Researcher*: So, you can notice something from this outcome?
> *Player*: Yeah! Like specifically from the science teacher [*being respected* and *being open-minded*]? So it means that I talked to him at lunch, others listen [because of that]. Without even talking directly with the math chairman, the math chairman is now slightly on board.
> *Researcher*: Right. Did you see the difference of that outcome, approaching the science teacher just now and the language arts chairwoman [only being *open-minded*] that you selected earlier?
> *Player*: The language arts chairwoman, like, I got points from those conversations [diffusion activity called "Talk to" in the DSG], but it seemed like I just convinced her *only*.
> *Researcher*: Right.

M-3.1. Pause the game to conduct part-task practice.

When supportive information was presented in a panel located next to the game space, some players did not know how to *apply* conceptual models and principles in the supportive information on DSG game strategies, and some did not *adapt* their game strategies on the basis of simulation game outcomes from their gameplay (see de Jong & van Joolingen, 1998).

In a complex learning situation such as in the DSG, simply providing supportive information does not ensure that learners will interpret game outcomes correctly. One way to assist them is to use part-task practice (van Merriënboer, Clark & de Croock, 2002). That is, provide additional practice on recurrent constituent skills in order to help learners reach a required level of automaticity. Part-tasks have various forms, and, in this study with simulation games, a matching task was used (Reigleuth & Myers, 2012).

The way that part-task practice could work is that, when a player is observed to commit repeated errors and is making little progress, time is frozen within the game and a virtual mentor interjects an appropriate part-task practice activity. The matching activity illustrated in Figure 6 was developed by Enfield (2012) and used also in the present study.

In Diffusion of Innovations (DoI) theory, it is important to employ diffusion activities that have been found to be empirically effective, depending on a person's phase of adoption. In the DSG, the goal is to move teachers through awareness, interest, and trial phases, respectively, before they can adopt the innovation. For example, diffusion strategies to increase *awareness* of an innovation are different from those that are more effective in the *trial* phase. Thus, the task is to *match* diffusion activities that are more likely to be effective at each phase of adoption. In this study, corrective feedback is provided when a player makes an incorrect match. Upon determining that a player has reached a standard of mastery by correct performance, s/he returns to the game space where time is unfrozen (Reigeluth, 2011). The part-task practice illustrated in Figure 6 cues players to differences in adoption phases (via icons and brief definitions), and requires them to *infer* properties of various diffusion activities (based on their description) which make each diffusion strategy a better match for one phase of adoption versus another.

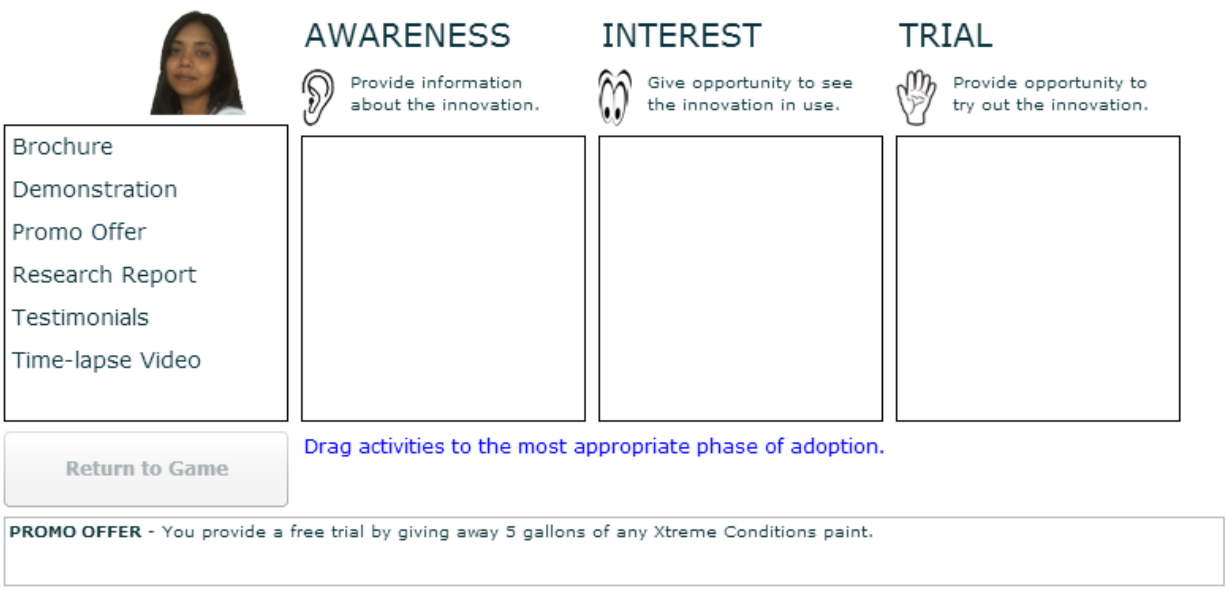


Figure 6. Part-task practice (match each diffusion activity with the appropriate adoption phase)

M-3.2. Incorporate part-task practice using a scenario identical to that in the game.

The scenario illustrated in Figure 6 was different from that in the DSG itself. While it was designed as a *transfer* task (i.e., players were expected to then apply what they learned to the DSG), it apparently was increasing cognitive load. For example, player 4 said that the *matching task* (part-task practice) was not helpful for interpreting game data in the DSG "because it does not directly correlate to the DSG, because they are different things. I was *not* connecting that activity to the task." Two players referred it as "confusing."

Note that the *mission context* (Schank, Fano, Bell, & Jona, 1993) of the part-task practice of matching each diffusion activity with the appropriate adoption phase was not based on the DSG; instead, it focused on trying to convince a house painter to adopt a paint brand. Even though the *mission* was the same, and only the *cover story* was different, extraneous cognitive load (imposed on working memory) seemed to occur. The *split-attention effect* (Kalyuga, Chandler, & Sweller, 1999; Mayer & Moreno, 1998) occurs when two or more sources of information must be simultaneously processed to derive meaning from subject matter. This probably occurred during part-task practice in our study and possibly interfered with learning.

Qualitative data from the preference survey indicate that, while part-task practice should stay in the game, it should be revised to be within a scenario *identical* to that given in the game. The suggestion of this design principle may be particularly applicable if a game is complex and relatively short, such as the DSG. Note that this is one of several possible solutions that could be considered.

M-4.1. Consider changing the simulation game to make it less complex, or create a series of games that proceed from least to most complex.

The goal of this study was to inspect further and analyze more deeply problems that participants encountered in game-based learning and to investigate IO methods that might address these problems. For this goal, instead of redesigning the game (*adjusting*), JIT feedback or tips were provided (*coaching*); or appropriate activities were conducted while the DSG was paused (*instructing*).

Adjusting aspects of a game and task classes could also be considered. Task classes are groups of tasks at the same level of complexity (van Merriënboer & Kirschner, 2007). In fact, this is what Enfield (2012) did in his study. He modified the original DSG into a series of new games, each with different scenarios. These new games were based on task classes arranged from simple to complex, in order to prepare players for the full version of the original DSG. He utilized *Ten Steps to Complex Learning* as a design theory (van Merriënboer & Kirschner, 2007).

This adjustment required a large amount of new development, creativity in new game design, and considerable software engineering to carry out each new game. In Enfield's study, intrinsic cognitive load was apparently reduced and novice players appeared to experience success in gameplay as they proceeded through increasingly more challenging games until they reached the level of complexity of the original DSG itself. This approach, referred to as *adjusting* the simulation game (Reigeluth & Myers, 2012), was very labor intensive compared with the IO methods used in our study. In contrast, we did no new game design or development, and no new software engineering; rather we developed instructional overlays (coaching and instructing) as additions to a mini-version of the original DSG.

M-5. Explicitly teach game content knowledge.

A frequently uttered claim about learning with simulations is that the learners should know something about the content knowledge beforehand, if the simulation-based learning is to be fruitful. This was not the case for the players in this study. They were not given any information about DoI theory and had not played the DSG before. Insufficient prior knowledge might be a reason that players often did not know which hypothesis to state, engaged in unsystematic experimentation, and were unable to interpret data appropriately (de Jong & van Joolingen, 1998; Glaser et al., 1992; Lara , Enfield, Myers, & Frick, 2010).

Several authors have recommended direct access to an IO before interacting with simulations and stated that it would reduce intrinsic cognitive load (van Merriënboer & Kirschner, 2013). The IO could be in a form of an interactive computer tutorial on DoI theory.

Or, possibly the series of simpler simulation games developed by Enfield (2012) could be played before starting the DSG, serving as an IO to the DSG itself (see M-4.1 above).

In this study, participants were selected who had no prior knowledge of DoI theory and who had never played the DSG. This could, and does, happen to many people who discover the DSG on the Web, and immediately try to play it. This observation served as the impetus for the present study, to identify what kinds of problems such players experience under these conditions. In an instructional context, it would clearly be beneficial for players to have opportunities to directly learn content relevant to the simulation game before they play it, or between games. Guidelines for designing this kind of instructional overlay are not included in Table 1. Instructional designers could, for example, use First Principles of Instruction (Merrill, 2012) or Ten Steps to Complex Learning (van Merriënboer & Kirschner, 2013) as guidelines for creating such an instructional overlay tutorial.

M-6. Debrief players.

In addition, *debriefing* is an important activity after players participate in a simulation or game (e.g., see Thiagarajan, 2004). Debriefing typically involves discussion of player experiences to help them connect those experiences with important content the simulation game is designed to help them learn. Debriefing was also excluded in the present study for the same reason as exclusion of a tutorial on DoI. Outside a normal instructional context (e.g., classroom, training workshop, or online course), it would be impractical to debrief to players after online DSG gameplay due to very large numbers of players. For debriefing in a normal instructional context, a job aid has been provided with the original DSG in order to facilitate instructor debriefing with students (see Appendix A).

These IO methods are included at the bottom of Table 1, but were not investigated in the present study.

Conclusion

Praxiological Theory Development

Formative research methods were used to develop and improve an instructional design theory for complex simulation games. This DTIO is summarized in Table 1. Reigeluth and Frick (1999) contend that formative research is an appropriate and effective way to develop what Steiner (1988) refers to as praxiological theory—in contrast to quantitative methods aimed at developing and validating scientific theory. Steiner (1988) has distinguished important differences among scientific, praxiological, and philosophical theories. The type of theory developed in this study is *praxiological* because it is concerned with instrumental value—that is, effective ways to guide student learning. On the other hand, scientific theory is valued for its own sake, without considering its utility (Krippendorff, 2007; Steiner, 1988). Praxiological theory differs from philosophic theory in that the former focuses on effectiveness (instrumental value), while philosophic theory pertains to worthwhileness (intrinsic value).

Thus, design theory for instructional overlays for complex simulations is expected to have instrumental value. Guidelines listed in the DTIO in Table 1 are expected to be useful methods for instructional designers who aim to improve the effectiveness of complex simulation games in terms of student learning achievement.

Readers should note that only *one* simulation game was examined in this research study: the DSG. It is possible that recommendations for guidelines in the DTIO proposed here might not be salient for other simulation games. It is also possible that specific features of the DSG did not provide opportunities for different kinds of learning problems to emerge that might occur in other simulation games. Hence, specific design guidelines for other simulation games could be missing in the current DTIO, since there was no evidence that they might be needed.

Need for Future Research

Further studies of the revised DTIO for instructional simulation games are needed. By repeated formative research studies with larger samples, the DTIO can be further improved.

In this research study, one of the authors served as a human mentor who simulated the system's intelligence and interacted with the user. Future researchers could try to replace human mentors with artificial intelligence agents, which have a feature that allows students to "freeze time" when they encounter a learning gap that they need to fill in order to proceed with the simulation.

Further, researchers could take into consideration how IO tools can be used as unobtrusive measures (Shute, Ventura, Bauer & Zapata-Rivera, 2008). For example, a player goes through a diagnostic problem-solving process in the game by choosing from a menu of actions. This process helps a player during the planning process. It also helps researchers (i.e., via the simulation game being run by a computer system) assess the learner's intentions, and examine their actual state of knowledge and keep track of what competencies each player has mastered. Therefore, diagnostic information about a player could be utilized when generating hints or prompts as adaptive instructional overlays.

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Appendix A

The Diffusion Simulation Game (DSG)

The DSG was selected as a case for complex simulation game in order to conduct formative research on a design theory for instructional overlays (DTIO). The DSG is based largely on Rogers' (1971) description of diffusion of innovation (DoI) theory. The goal of the DSG is to provide a virtual scenario within which students can put into practice their knowledge of and skills related to the DoI theory. Rogers' theory, developed initially in 1962, explains the process by which new ideas and practices spread between and within social systems.

In the 1970s, a board game version of the DSG was developed and evaluated (Molenda & Rice, 1979). In the DSG, the student plays the role of a change agent in a junior high school. Change agents are individuals who generally work for a change agency. Their goal is to secure adoption of a particular innovation by a group of people. A player's mission is to successfully diffuse the implementation of a specific instructional strategy in the school, persuading up to 22 staff members to adopt the innovation. Players need to consider different elements of DoI theory in order to succeed in a game; these elements include types of diffusion activities, adopter types, adoption phases, social networks, opinion leaders, gatekeepers, and communication channels.

In 2002, an online version of the DSG v.1.0 was developed as part of an online course at the School of Education at Indiana University on the topic of change management strategies. In the online course, the DSG has been used with prior instruction, as well as prior readings and discussion with peers. After gameplay is completed, students normally participate in a debriefing session about the DSG and DoI theory.

Since its introduction in 2002, the DSG has also gained popularity outside of formal coursework. Over 10,000 gameplays of the free, public version occurred between October 7, 2006 and April 4, 2009 (Enfield, Myers, Lara, & Frick 2011). As of May 1, 2012, an additional 13,000 gameplays have been recorded.

In 2010, a newer version of the DSG, known as DSG 2.0, was developed. This version has several technical improvements over the previous version. DSG v.1.0 is available on the Web at https://www.indiana.edu/~simed/diffusion/index.html. DSG v.2.0 beta is available at: http://www.indiana.edu/~simgame/beta/dsg.html. In order to reduce playing time and player mental fatigue, authors of this report used a simplified version, called the DSG mini version. The number of staff members in this version was reduced from 24 to 12 and the number of diffusion activities was reduced from 13 to 7.

The original DSG itself does not include any instructional overlays. Without additional support (e.g., IOs, knowledge of DoI theory, instruction in a formal course, debriefing), highly motivated learners can easily spend 30 or more hours playing the DSG and still fail to get a majority to adopt the innovation. The DSG is difficult and complex, attempting to mirror the reality of diffusion of innovations.

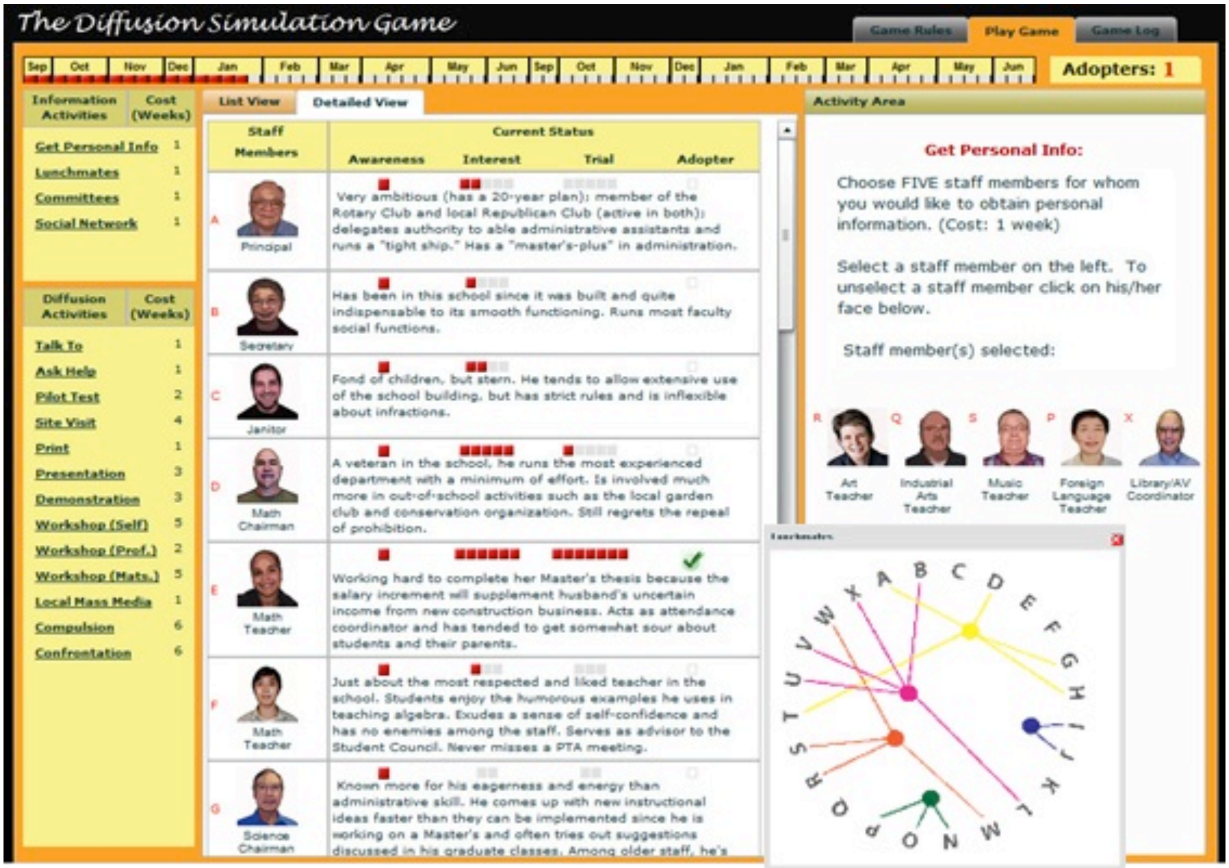

Figure 3. DSG v.2.0.