Combining Serious Gaming and the Holodeck

How Serious Gaming and a Holodeck May Support Each Other

Rob Schuddeboom

Master Thesis Information Sciences

Combining Serious Gaming and the Holodeck

How Serious Gaming and a Holodeck May Support Each Other

Rob Schuddeboom

Master Thesis Information Sciences

October 2008

VU University:

supervisor: dr. A. Eliëns
co-supervisor: prof.dr. G. van der Veer

Getronics PinkRoccade:

supervisor: M. de Haas
co-supervisors: J. Gerbrandy, T. Thijssen

Preface

This report serves as a graduation thesis for my master Information Sciences at the VU University Amsterdam. The research was conducted at Getronics PinkRoccade, within the department Business Application Services, Business Innovation.
This research focuses on the subject of serious gaming and the “Holodeck” concept that has been developed at Getronics PinkRoccade. It deals with methods and elements for the development of serious games, identifies methods that can be used to measure their effectiveness, refines the definition of a Holodeck and its purposes and explores the possibilities for combining these two concepts in useful ways.
This report is primarily intended for Getronics PinkRoccade, which may use it to determine ways in which serious gaming and a Holodeck may be used within the organization. It may also be of use to anyone else who is interested in serious games and measuring their effectiveness, or in the concept of a Holodeck and ways in which it might be used.

I would like to thank Martin de Haas, Theo Thijssen and Jelle Gerbrandy for their advice and supervision during this research at Getronics PinkRoccade, as well as Anton Eliëns and Gerrit van der Veer for their advice and supervision at the VU University Amsterdam.
Pieter van Prooijen at Getronics PinkRoccade also has my thanks for providing me with advice during this research.
Furthermore, I would like to thank the Belastingdienst, especially Joseph van der Steen and everyone of the PoC group, for providing me with information and advice for my case study and my research.

Rob Schuddeboom

Abstract

This research will deal with the subject of serious gaming and the concept of a “Holodeck”: a simulation environment in which people may experience and experiment with a certain “reality”.
Both of these concepts will be discussed, after which the possibilities for combining them in beneficial ways will be explored, as well as the methods that may be used to measure the effectiveness of serious games.
It will be concluded that a Holodeck may support serious gaming in the form of openness, physical situatedness, increased realism and the support of a reflective learning strategy and an overall training program, while serious gaming may provide advantages in the form of attractiveness and guidance in the form of game elements and visualization and interactive simulation by means of game technology. Such advantages can not be provided in every case and their usability may depend on the purposes of a Holodeck or serious game, the content of the simulation and a number of distinctions in the way in which a Holodeck is used.
The research will also identify a number of assessment methods for serious games, based on methods in traditional learning environments, useful game characteristics and serious gaming specific methods for assessment. Most of these methods may also be used in a Holodeck environment with a learning purpose.

Index

1. Introduction

1.1 Context

At the start of this research Getronics PinkRoccade (GPR) was developing a new information system for the “Belastingdienst”, the Dutch tax collectors office, meant to support the processing of “toeslagen”. The original goal of this research was to explore the possibilities for training and familiarizing end-users with this new system and the new work process that went with it by means of serious gaming, the use of video games for a serious purpose. At the same time, this research would explore the possibilities of a new concept called a “Holodeck”, which was being used during the design process of the system for the Belastingdienst.
The Holodeck is a room in which a (work) process can be simulated, allowing people to experience what a certain process and system may look like and how they may be used. The Holodeck contained tools to support presentations and feedback sessions as well. Such an environment seemed to be useable for training purposes and change management as well. Serious gaming, which was already being researched at GPR to explore the possibilities for its use within the company, was seen as a useful tool that might be added to the Holodeck at the Belastingdienst. Unfortunately, there was little time to develop such a game and in the end the Belastingdienst decided it was best to stick to the tools for training and change management they already had. So, there was no longer an opportunity to explore the possibilities of serious gaming, a Holodeck and a combination of the two in a case study and it was decided to research these topics with a more theoretical, hypothetical approach instead.

1.2 Problem statement

Serious gaming is seen as a useful tool for a Holodeck, because it may provide rich visualizations, present people with clear goals during a simulation, guide them by means of rules and a storyline, provide them with the necessary context and enhance the overall attractiveness of the simulation. At the same time, a Holodeck, as an environment in which people are engaged in a simulation of a different reality, might serve as a tool to enhance the realism or attractiveness of serious games and provide a simulation that is more open for experimentation. The possibilities for the combination of these two concepts will have to be explored in order to be able to use them effectively.
In order to do this, the way in which a good serious game can be developed and how learning can be achieved in such a game will first have to be determined. Since serious gaming is a new concept at GPR that still has to prove its value, it is also useful to define ways in which the effectiveness of serious games can be determined. Useful measuring and observation techniques will have to be explored. At the same time, the concept of a Holodeck will have to be explored and documented further, determining the form or forms it may take and the purposes it may serve.

1.3 Research questions

The problem statement above leads to the following research question, which will be dealt with in this text:

> Which design techniques can be used for the development of effective serious games, how can this effectiveness be determined and how can serious gaming and a Holodeck environment support each other?

To answer this research question, a number of sub-questions will be addressed in this text:

- Which design techniques and game elements can be used for the development of effective serious games?
- What are possible ways for measuring the effectiveness of serious games?
- What is a Holodeck and what purposes may it serve?
- What are the possibilities for combining serious gaming with a Holodeck environment and which advantages may this provide?
- Does a Holodeck require or facilitate alternative ways of measuring effectiveness?

1.4 Research method

This research will start with a literature review aimed at finding techniques and criteria for designing serious games and making effective learning tools out of them. This will be followed by a literature review aimed at identifying the possibilities for measuring the effectiveness of serious games.
After this, the concept of a Holodeck will be defined in more detail and the possibilities for its use will be explored. This will be done by interviewing the inventor of the concept "Holodeck" at GPR, as well as by looking at similar concepts that already exist in other places to identify alternative interpretations of a broader term.
Once the goals, elements and methods of serious games and a Holodeck have been identified these will be compared to identify ways in which serious games and a Holodeck environment may support one another. The Holodeck developed for the Belastingdienst will serve as a case study in this discussion.
The methods for measuring the effectiveness of serious games identified in the literature study will also be compared with the concept of a Holodeck, to see in which ways such an environment may restrict or facilitate the use of these methods. After this, conclusions can be drawn and possibilities for future research will be explored.

2. Serious Gaming

Serious gaming, more and more often this term can be heard nowadays, but what exactly is a serious game? And what makes a serious game useful and successful? In this chapter the concept of serious gaming will be discussed in more detail, together with the issues and methods that are relevant in the design process of serious games. In section 2.1 a definition of serious games as it will be used in this document shall be given. Next, in section 2.2, the techniques and elements that contribute to, or are necessary for the creation of a successful, effective serious game will be dealt with. In section 2.3 a number of theories of learning that are relevant for learning with serious games shall be discussed.

2.1 Defining serious games

A short definition of serious games can be found at Wikipedia [45], which gives a reasonable impression of the meaning of the concept:

> *"A serious game is a software application developed with game technology and game design principles for a primary purpose other than pure entertainment."*

A similar short description is given by Michael and Chen [24], which is the following:

> *"A serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment."*

This should provide a general idea of what a serious game is, but to facilitate further discussions about serious gaming it seems useful to provide a somewhat more detailed definition. To reach such a definition, it is useful to split up the term "serious game" into two parts and look at the question: what exactly is a game?

2.1.1 Definition of game

Often, a definition of the term "game" is given by describing a list of elements. Prensky [33], for example, uses a list of six game elements: *rules, goals and objectives, outcomes and feedback, conflict/competition/challenge/opposition, interaction* and *representation/story*.

Leemkuil [19] uses the following definition of game, in which most of the elements that Prensky [33] mentioned can also be found:

> *"Games are competitive, situated, interactive (learning-) environments based upon a set of rules and/or an underlying model, in which, under certain constraints and uncertain circumstances a challenging goal has to be reached."*

Michael and Chen [24] give a definition that includes some other, but also some similar characteristics, based on a list of six characteristics of "play" given by Huizinga [13]:

> *"Games are a voluntary activity, obviously separate from real life, creating an imaginary world that may or may not have any relation to real life and that absorbs the player's full attention. Games are played out within a specific time and place, are played according to established rules, and create social groups out of their players."*

Although playing a serious game will not always be a voluntary activity, such as a game played in a classroom or during training, and although digital games do not necessarily have to be played with other people, most of these characteristics are relevant. In section 2.2.1 the different elements of a game and their importance in the design process of a serious game will be discussed in more detail.

2.1.2 Definition of serious game

The definition of game as it was given above is a definition in the general, broad sense of the word. The definition covers computer games, but also includes board games and role playing games. The term serious game however is restricted to computer games only, that is: games that are played using electronic devices, such as a PC or a game console.
In another way the concept serious game is also broader than the concept of game, because, according to Zimmerman [47], applications that do not contain game elements, but that do use game technology, such as flight simulators for the training of pilots and 3D models of buildings for use by architects, also belong to the collection of serious games. Nevertheless, the focus in this document will be on serious games that do include game elements.

The "serious" part of serious games can be found in their goals. As it was already stated in the short definitions given earlier, the goal of a serious game is something other than pure entertainment or fun. By this, serious games distinguish themselves from games created by the entertainment industry. Often, the goal of a serious game is to allow the player to learn something, as is the case with education and training for example, but serious games can also, as Michael and Chen [24] point out, be used for other things such as the promotion of products or for creating awareness for a certain subject. The only real limitation is that the goal of a serious game has to be "serious".

To summarize the information above a definition of a serious game will now be given, as it will be used in the context of this research:
A serious game is a software application that uses game technology and game design techniques and contains game elements, which it uses to reach a serious goal, other than pure entertainment.

2.2 Important elements and methods for serious game development

Now a definition of serious games has been established it is important to look at the elements that should be present in a successful serious game and at techniques that can be useful during the development of a serious game. A number of these elements and techniques will be discussed in this section.

2.2.1 Basic elements of games

In section 2.1.1 a number of definitions of the term “game” have been given, in which a number of important elements of games have been mentioned. These elements are also useful to consider in the development process of a serious game. Therefore, these elements, as they are given by Leemkuil [19] and are used by Zimmerman [47], will now be discussed in more detail.

A challenging goal
One of the properties of a game is that it always has a goal. Goals are strongly related to the element of competition, which will be discussed below. Leemkuil [19] distinguishes three different types of goals, which can be used in combination with each other:

- Solving a certain problem or a series of problems
- Reaching a higher level of skill or efficiency, such as beating a personal “high score”
- Beating a group of other players

According to Malone [21] the presence of a goal in a game has a positive influence on the motivation of the player to keep playing. He claims it is important that the goals and the ways in which these can be accomplished are clear, specific, meaningful and challenging.
Although the goals of a game are often predetermined by its developers it is also possible to allow the players to set their own goals. A successful example of this is the computer game The Sims.
As Leemkuil [19] points out, the difficulty of reaching the goal should be well balanced. If a goal is too easy to reach players will miss the challenge and might stop playing. If a goal is too hard to achieve players might get frustrated, in which case they might also stop playing. Therefore, it is not a bad idea to implement an adjustable level of difficulty into a game, so the players can set this to the desired level of challenge themselves.

Rules and an underlying model
Every game has rules to indicate which actions are possible and which actions are not and to determine how the game proceeds. By means of rules, the ways in which players can reach a certain goal can be restricted, creating challenge. As Leemkuil [19] points out, on the other hand, one should also make sure that enough possible actions remain. This will give players the idea that they can determine their own strategy in the game, which will keep them interested in the progress of the game.
The desired amount and complexity of rules (or the underlying model) will also differ among players. Some will be happy with a game that is easy to learn and can be played quickly,

while others will prefer a game with a large amount of possibilities and relatively high complexity.

If games, or simulations, become more complex, the extent to which the rules or the underlying model will be made known to the player will also start playing an important role. It is not always necessary that a player is aware of and understands the entire functioning of an underlying model. It can even be more challenging to withhold an explicit explanation of certain rules from the players, which allows them to discover the relevant general relationships between a certain action and the reaction of the environment for themselves by experimenting in the game. A game can also be made less complex and more fun to play by letting some rules play their part only on the background of the model, out of view of the players. This will prevent them from having to focus on irrelevant details. Nonetheless, in serious games, the extent to which the underlying model is known to the players is of greater importance than in entertainment games. It allows the players to learn the functioning of the underlying model. Abt [1] says the following about this:

> "*No serious game can be successful if the players do not understand its rules, their objectives in the game, the consequences of their action, and the reasons for these consequences. In this sense, serious games should differ from more conventional games. They should respond more to the conscious decisions of the players than to an outside element of chance.*"

Competition

A game should contain a certain form of competition. Competition is strongly related to the achievement of goals and is also meant to make a game more challenging. Leemkuil [19] distinguishes four different forms in which competition can take shape:

- Beating the system.
- Beating yourself, by improving your performance in the next game round.
- Beating other players in a direct confrontation.
- Beating other players by performing better than they did in previous rounds.

Furthermore, a distinction can be made between games in which players compete with each other in one game environment which can be influenced by all of them in certain ways and games in which all players play in their own environment and competition is created by comparing the achieved results of the players, such as a certain score or the present state of the environment.

Interaction

Another characteristic of games is that there always is a certain form of interaction that takes place. An action of the player leads to a change in the game environment and is followed by an action of another player or the system. Players should receive feedback in which the reactions of the game are made clear, to allow them to determine whether they reached their goal or got any closer to it. In this way, players can learn whether certain actions are useful for achieving certain goals or not. In section 2.3.4 the role of feedback in the learning process in serious games will be discussed in more detail.

Uncertainty
Uncertainty is an important element of games. Although the goals of a game might be clear, uncertainty can make it unclear for players if and how these goals can be reached. Leemkuil [19] lists four types of uncertainty:

- Uncertainty about the actions of other players or those of the system.
- Unexpected events that are introduced into the game environment.
- Chance or coincidence.
- The fact that not the entire game environment, or the underlying model is made known to the player at the start of a game.

This uncertainty stimulates the players to explore the game environment, try out different strategies and take certain risks. Uncertainty contributes to the challenge and variation in a game. In the case of serious games however, as was mentioned before in the citation of Abt [1], developers should make sure that the players understand the working of the underlying model correctly and there should be a stronger focus on their actions and the reactions of the system than on chance. Nonetheless, uncertainty can also play an important role in serious games, as people have to deal with uncertainty in real life too. An example of this is the uncertainty about the actions of other people that was mentioned above.

Situatedness and story
A game is often placed in a certain context: an imaginary situation with a certain story. In most cases the player will be assigned a certain role and will for example be able to inditify him- or herself with a certain character. The imaginary situation may prickle the fantasy of players. In a game it is possible to take up a role which can seldom or never be encountered in real life. Games also have the characteristic to stand loose from reality. Actions within the game only have an influence in the game environment and not in the real world. This improves the value of games as a learning environment, since players can experiment and make errors without any negative consequences in reality.
The fantasy that is stimulated by the context and story of a game can also make a positive contribution to serious gaming, as is suggested by Rieber [36]. Rieber distinguishes two ways in which fantasy can play a part in educational games. An exogenous fantasy, in which fantasy is separated from the content and functions as a way of making learning of the content more attractive and an endogenous fantasy, in which fantasy and content form one whole and cannot be distinguished from one another. According to Rieber [36], the advantage of an endogenous fantasy is that if the players are interested in the fantasy, they will also be interested in the content that is to be learned. This will lead to intrinsic motivation to play and learn.

2.2.2 What makes computer games attractive?

One of the reasons that is often given to defend the use of a game as a method of teaching or a way of reaching another kind of serious goal is that games are attractive. In the discussion of game elements earlier in this text some of the things that can make games attractive have already been mentioned. In this section the discussion of what makes a game attractive will be handled in more detail and ways of achieving this attractiveness will be described. In this discussion the focus will be on computer games, rather than games in general.

In literature a number of elements can be found that are considered to make a computer game attractive. McFarlane et al. [22] have made the following summary of these:

- fantasy
- challenge
- curiosity
- *engagement* caused by *flow*

Fantasy has already been mentioned earlier in the discussion of game elements. Because fantasy is a standard element of games this causes them to be more attractive by definition. Challenge is also retraceable to the game elements described earlier, such as goals, rules, competition and uncertainty. That computer games are able to cause curiosity is confirmed by both Malone [21] and Amory et al. [3], among others.
Another feature that makes computer games attractive is their ability to maintain a high level of *engagement* of the player. This feature was even considered to be part of the definition of games given by Michael and Chen [24], as it was given in section 2.1.1. Engagement is related to the concept of *flow*, a term that comes from the theory of Csikszentmihalyi [9], in which flow can be summarized to be a state in which a person is involved in a process in such a way that all other things are no longer relevant. Based on this theory, Malone [20] comes with a number of conditions which should be met during the development of a game to allow the player to experience the flow. The list below is the translation of a summary by Zimmerman [47].

- The activity should be structured in a way that allows the player to adjust the difficulty of the game to put the challenge more in line with the skills of the player.
- It should be possible to easily distinguish, at least visually, the activities from other stimuli; otherwise, the engagement will be disrupted.
- There should be clear performance criteria. Players should be able to evaluate their performance at any point in the game.
- The activity should result in concrete feedback which allows the players to determine to what extent they met the performance criteria.
- The activity should present the player with a wide range of challenges of different levels of difficulty in a way that gives the players more and more complex information about multiple aspects of themselves.

If this flow of engagement can be reached within a serious game it offers huge advantages compared to traditional methods of learning and communication, in which retaining attention has almost always been a problem. Michael en Chen [24] illustrate this with a message from CBS Evening News from februari 2005, in which it is reported that computer games were able to retain the attention of players for two to four hours at a time, while the average student in a classroom typically lost interest after about fifteen minutes.

2.2.3 Learning goals and suitable game genres

Computer games come in all kinds of shapes and sizes. To be able to classify computer games the entertainment industry uses a number of genres, as it is done for movies. Zimmerman [47] points out that these genres are subject to change and that it is possible that a game cannot be

placed into any genre, or should be placed into multiple genres. Still, just as with movies, classifying games according to genre often gives some insight into their content. This is also the case for serious games.
Because each game genre has its own characteristics it is possible to identify game genres that might be suited for reaching a certain serious goal, by looking for characteristics that support this goal. Prensky [33] has created a list of learning goals and possible game genres that support these goals. This list can be found in Table 2.1 on the next page. For an explanation of the different game genres I refer to Prensky [33], or Zimmerman [47] or Herz [12], who use the same classification. This classification can be useful for determining a suitable form for a serious game that should reach a certain serious goal. When using this list, designers should ask themselves what elements an indicated game genre possesses that make it suitable for reaching a certain learning goal.

Content	Examples	Learning activities	Possible game genres
Facts	Laws, policies, product specifications	Questions, Memorization, Association, Drill	Game show Competitions, Flashcard type games, Mnemonics, Action, Sports games
Skills	Interviewing, teaching, selling, running a machine, project management	Imitation, Feedback, Coaching, Continuous practice, Increasing challenge	Persistent state games, Role-play games. Adventure games. Detective games
Judgment	Management decisions, timing, ethics, hiring	Reviewing cases, Asking questions, Making choices (practice), Feedback, Coaching	Role play games, Detective games, Multiplayer interaction, Adventure games, Strategy games
Behaviors	Supervision, self-control, setting examples	Imitation, Feedback, Coaching, Practice	Role playing games
Theories	Marketing rationales, how people learn	Logic, Experimentation, Questioning	Open ended simulation Games, Building games, Constructing games, Reality testing games
Reasoning	Strategic and tactical thinking, quality analysis	Problems, Examples	Puzzles
Process	Auditing, strategy creation	System analysis and deconstruction, Practice	Strategy games, Adventure games, Simulation games
Procedures	Assembly, bank teller, legal procedures	Imitation, Practice	Timed games, Reflex games
Creativity	Invention, product design	Play, memorization	Puzzles, Invention games
Language	Acronyms, foreign languages, business or professional jargon	Imitation, Continuous practice, Immersion	Role Playing games, Reflex games, Flashcard games
Systems	Health care, markets, refineries	Understanding principles, graduated tasks, playing in microworlds	Simulation games
Observation	Moods, morale, inefficiencies, problems	Observing, feedback	Concentration games, Adventure games
Communication	Appropriate language, timing, involvement	Imitation, practice	Role playing games, Reflex games

Table 2.1 – Content that is to be taught and possible game genres. [33]

2.3 Theories of learning and serious gaming

In most cases one of the goals of a serious game will be to teach something to its players. In literature, there are a lot of theories about the way in which people learn and process information. In this section some of these theories, which are relevant for the development of serious games, will be discussed.
In section 2.3.1 different types of knowledge that exist will be discussed, followed by a discussion of different strategies for learning and information processing in section 2.3.2. After this, in section 2.3.3, it will be explained how different groups of people use different strategies for learning. In section 2.3.4 a number of techniques that can enhance learning in general, or specific ways of learning, within the area of serious games will be discussed.

2.3.1 Types of knowledge

Nickols [29] has made a distinction between different types of knowledge a person can possess. He makes a distinction between *explicit knowledge*, *tacit knowledge* and *implicit knowledge*. Explicit knowledge is knowledge that can be verbalized in formal, systematical language. Tacit knowledge is knowledge that cannot be made explicit, because this knowledge can't be brought to a conscious level, such as face recognition and taste. Implicit knowledge is hard to verbalize, but can be made explicit with sufficient effort. Usually implicit knowledge is based on experience. Zimmerman [47] says the following about this:

> "*Implicit knowledge is often embedded in a specific context (people, tools, procedures, etcetera), which makes it hard to transfer this knowledge because the receiver cannot place the knowledge correctly without the original context.*"

Zimmerman [47] points out that traditional methods of learning are quite suitable for transferring explicit knowledge, but have more difficulty transferring implicit knowledge and require more effort to do this.
Implicit knowledge can be transferred by letting a person look over the shoulder of an experienced person, who already possesses the implicit knowledge, but serious gaming can also be a useful method. The reason for this is that serious games offer the possibility to offer the player the context together with the knowledge that needs to be transferred and to allow for experiencing through simulation.

2.3.2 Ways of learning and information processing

Besides a distinction between different kinds of knowledge a distintinction can be made between different ways of information processing that people use as well. Leemkuil [19] distinguishes, based on a review of the research of Berry and Broadbent [6], Norman [30] and Taatgen [38], two strategies for the processing of information: an *experiential* strategy and a *reflective* strategy.

An experiential strategy is often used in learning environments that are dynamic, complex and low transparent. Computer games are such environments and therefore this strategy will be the first that players will use. When using the experiential strategy for information processing, players will start looking for cues that give an indication of the actions that are available that might get them closer to reaching the goals of the game. When the environment enforces the players to act they use these cues and information from past experiences with this game or similar situations to select a certain action or action sequence which they think is suited. They will use the feedback they get from the system to label this action as either a good or a bad action for that particular situation. This strategy requires some thought, but is mainly data driven and reactive. The costs of using this strategy are therefore low, especially if someone does not have a lot of basic knowledge of the task concerned. For this reason, players will often start playing computer games by using an experiential strategy.
The experiential strategy will lead to the acquisition of knowledge about the interface, procedures that should be used, concepts and situation-action pairs. This knowledge is intuitive, difficult to verbalize and hard to transfer to another context.
As long as there are cues available in the game environment or usable situation-action pairs in memory, players will keep using the experiential strategy. As soon as there are no more cues available or if the actions of the players do not seem to get them closer to reaching the goals of the game anymore, players might switch to a reflective way of information processing. When using a reflective strategy the players look back on their past behavior or the past behavior of others and abstract new rules, procedures and insights from this. This strategy requires more mental effort, structure and selective reasoning than the experiential strategy does. Leemkuil [19] suggests that the use of systematic procedures and methods and the aid of additional tools or other people can support players in using this strategy. This will be discussed in more detail in section 2.3.4.
The successful use of the reflective strategy will lead to new, explicit insights and strategies which can be applied by the players in other parts of the game or in similar situations. According to Leemkuil [19] a combination of both an experiential and a reflective way of information processing will result in the largest increase in knowledge, because both intuitive, implicit knowledge and explicit knowledge will be acquired this way.

2.3.3 Personal characteristics and learning

Just as the situation in which learning takes place and the content that is to be learned have an effect on the way in which people learn, personal characteristics have an effect on the way in which people learn effectively and comfortably as well. In the discussion about learning with serious games, it is useful to look at the concept "*game generation*" that was defined by Prensky [33].
The game generation is described as the group op people born after 1975 that has access to *new media* such as television, Internet, computer games, etcetera. These people have been confronted with new media since their childhoods, which caused them to develop a new way of information processing. Zimmerman [47] gives a short overview of the differences between this new way of learning of the game generation and the traditional way of learning of the non game generation, which can be found in Table 2.2. These differences will be explained below, also based on the summary that Zimmerman [47] gives of the work of Prensky [33].

New way of information processing	Traditional way of information processing
Twitch speed	Conventional speed
Parallel processing	Linear processing
Graphics first	Text first
Random access	Step-by-step
Connected	Standalone
Active	Passive
Play	Work
Payoff	Patience
Fantasy	Reality
Technology-as-friend	Technology-as-foe

Table 2.2 – A comparison of the new way of information processing used by the game generation and the traditional way used by the non game generation. [33]

Twitch speed vs. conventional speed
The game generation has learned to process information rapidly due to exposure to new media such as MTV, which presents information at a quick pace.

Parallel processing vs. linear processing
The human brain has the ability to process several tasks in parallel. If one takes a look at the younger generation it can be seen that this parallel processing is used often, as they can be found working with several applications running on their PC simultaneously, while both the TV is on and music is playing. Performing these tasks in parallel is something that many younger people have become quite good at, while the older generations are often more accustomed to a more linear approach.

Graphics first vs. text first
Graphics are used primarily as a support for text by the non game generation. For the game generation however, this relation is often inverted. From an early age, they have been subjected to expressive graphics without a lot of text, such as TV and computer games. Because of this, the visual sensitivity of their brains has increased, which causes the game generation to naturally process visual aspects first and then combine them with text to form a meaningful whole.

Random access vs. step-by-step
The Internet has, by means of hyperlinks, provided the possibility to follow less sequential paths for accessing information. This new structure of information has taught the game generation that thoughts do not always follow just one path.

Connected vs. standalone
The Internet offers more possibilities for communication, which the game generation has grown up with: e-mail, forums, news groups, multiplayer video games and instant messaging. These forms of communication are cheaper than for instance a telephone conversation and provide the opportunity for both synchronous and asynchronous communication. As a result of this connectivity the game generation has developed a different viewpoint on the ways in which information can be obtained. If you have a problem you can post it on a forum which gives possibly thousands of people the opportunity to give you advise.

Active vs. passive
If a member of the non game generation purchases a new piece of machinery or software, he or she is likely to first study the manual extensively out of fear of breaking something. This is

not the case for a member of the game generation, who will directly start using the new piece of machinery or software and will start trying out the available actions to discover how it functions. Their purchase is expected to support this strategy.

Play vs. work
The game generation sees work as a form of play. Although they take their work seriously there are elements of work, such as completing a task, winning, or beating the competition, which can also be found to be elements of play.

Payoff vs. patience
By playing computer games the game generation has learned that investing a lot of time and effort into something will eventually be rewarded. In games it is often obvious what the goals are and what rewards and investments are related to them. It is up to the player to decide whether this reward is worth their while or not. This has caused the game generation to have a low tolerance for ongoing absence of an expected reward after a certain investment has been made.

Fantasy vs. reality
Fantasy can be found in every human being. The fantasy of the game generation however is being stimulated by all new kinds of technology and as a consequence it has become quite large.

Technology-as-friend vs. technology-as-foe
The non game generation sees technology as something to be afraid of, to tolerate or at best to be used for their own purposes. The game generation however sees technology as a friend and a useful tool.

Beck and Wade [5] also speak of a new way of learning that has come forth out of playing computer games. This new way of learning:

- "*Agressively ignores*" the structure and format of formal instruction.
- Is built on extensive trial and error, with a "*failure is nearly free; you just push play again*" mentality.
- Includes input and instruction from peers (other gamers), not authority figures.
- Emphasizes "just in time" learning, with new skills and information picked up just before they are needed.

These new ways of learning seem to share some characteristics with the experiential learning strategy that was described earlier. Serious games will therefore be highly suited for supporting this new way of learning. Although a hard line between game generation and non game generation is drawn by Prensky [33] by mentioning the year 1975, the difference in the use of learning strategies will not always be this sharp in everyday life. Zimmerman [47] says the following about this:

> "*There are a lot of people of the non game generation that are perfectly capable of adapting to new technology and thereby to new ways of information processing as well. It is unclear how well or how bad people of the non game generation would be able to cope with this new way of information processing, if all training and education were to be done according to this new strategy.*"

Whatever the answer to these last words may be, for the coming years, it seems wise to think about methods to support both members of the game and the non game generation in their ways of learning when developing serious games.

This difference between generations is not the only thing that causes different people to learn effectively in different ways. Prensky [33] distinguishes four factors which are relevant for the development of a serious game that will be played by a diverse workforce. Two of these (age and experience with computer games) can be connected to the difference between game and non game generation mentioned earlier. Besides these, however, there are two more factors that are relevant.

- *Age*: Older employees often prefer traditional training methods, while younger employees often prefer more interaction.
- *Gender*: There is a difference between the kind of games that men like to play and those that women like to play.
- *Competition*: Some players like to play competitively, while others prefer to play cooperatively.
- *Experience with computer games*: Not all employees will have an equal amount of experience with playing computer games. An intuitive user interface is required for players with no or little experience.

Prensky [33] recommends asking the players for input and preferences. He also advises to supply the information of a serious game in a traditional format as well, for those people that do not like games, or this specific game. There are people who like learning in the traditional ways.

2.3.4 Support of reflective learning

It was mentioned earlier in this text that people who are playing a game will primarily use an experiential strategy for processing information. To support the acquisition of explicit knowledge and understanding of complex concepts and relationships it can be desirable to support a reflective learning strategy as well in a serious game.
Leemkuil [19] discusses a number of tools and methods that have been described in previous literature as supporting the use of a reflexive way of information processing. These are: *feedback, guidance, additional assignments, cooperaton and collaboration, debriefing and group discussions* and *monitoring facilities*. A number of these methods can be incorporated into a computer game itself, but a number of other methods will fall outside the scope of the game and will instead support it as part of the learning process that surrounds it. How all of these methods can contribute to a reflective way of information processing in serious games will be discussed below.

Feedback
Each game provides some kind of feedback which directly or indirectly shows whether players are getting closer to their goals or not. Leemkuil [19] uses the example of a flight simulator to illustrate this, in which case players can for example directly see for each landing whether it was a safe landing or not. By performing a large amount of landings and getting

this kind of feedback it is possible for a player to get some intuitive insight into how to perform a landing. To be able to support a reflective way of information processing that can lead to new explicit insights however, additional feedback is required that gives the player more information about the process, such as velocity, wind direction and steepness of the descent. By comparing this information for different landings players can discover new rules about how to proceed under certain circumstances. In many cases however, even this information will still not be enough because the player does not know which information is relevant and he or she will not be able to discover the essential relationships between the available data. In these cases it is also necessary to offer the possibility to compare the actions of the player with good or bad methods together with their underlying rationale as a form of reference data. Feedback should support the player in generating a multitude of hypotheses and rejecting erroneous ones.
The moment at which feedback is given and the way in which feedback is presented can also be of importance for the stimulation of a reflective strategy. Leemkuil [19] points to research of Munro, Fehling and Towne [27], in which a group of students that was presented with an error message as soon as the system discovered an error, made considerably more mistakes than a group of students who were only presented with the error message after clicking on a certain button first. Leemkuil [19] summarizes the role of feedback as follows:

> *"It appears that the type of feedback and the moment at which it is given have an influence on the information processing strategy that students will use. To support a reflective strategy feedback should not be goal or outcome directed, but should help the recipient to evaluate hypotheses by giving process data."*

Guidance
In some cases, feedback in itself is not enough to stimulate a reflective way of information processing. Especially in cases where actions lead to a large amount of changes in the game environment, or in cases where large amounts of information are available it can be necessary to provide players with additional help to encourage a reflective strategy. In these cases hints and prompts can be given, or a coach or advice system can support the player in organizing the available information and stimuli and selecting the relevant elements and focusing on the relevant relationships between them. This kind of guidance can result in increased performance and knowledge, although in part of the research that Leemkuil [19] discusses it is not clear whether this concerns intuitive or explicit knowledge.

Additional assignments
The introduction of additional assignments into a serious game or into the overall learning environment has also been mentioned as one of the ways to encourage a reflective way of information processing, by Reiser [34] among others. Additional assignments offer the possibility to make a task more problematic or to focus the attention of the player on aspects that might otherwise have been overlooked or taken for granted without any mindful processing of this information. By introducing additional assignments one can prevent the player from rushing through the problems without taking the time to consider the subject matter that is to be learned during the game.
As with research concerning the effects of feedback and guidance, there is also research that suggests that the use of additional assignments will increase intuitive knowledge rather than explicit knowledge. According to Leemkuil [19], the reason for this could be that the

assignments that were used were too directive. "*They tell students what to do, help to discern important variables and to set goals and in that sense they make the task easier to perform. This could reduce the need to use a selective reflective mode."* As stated before, according to Reiser [34] it is therefore necessary to come up with questions that make a task more problematic or focus on aspects that might otherwise be overlooked to stimulate the use of a reflective strategy.

Cooperation and collaboration

Collaboration with other people has a positive effect on learning in general and especially on using a reflective strategy for information processing. According to Veerman and Veldhuis-Diermanse [41] collaboration can provoke activity, make learning more realistic and stimulate motivation. Leemkuil [19] states that people in collaborative settings are "forced" to share perspectives, experiences, insights and understandings. According to Zimmerman [47] it is this "necessity" to share that helps learners to make their implicit knowledge explicit.
It is necessary to make a distinction between cooperation and collaboration in this discussion. Leemkuil [19] provides the following distinction based on that given by Van Boxtel [8]:

> "*Examples of co-operative learning groups are those in which students help each other while still maintaining their own worksheet, and group in which each student does a different part of the group task. In contrast with co-operative learning groups, in collaborative peer workgroups students try to reach a common goal and share both tools and activities.*"

In the field of serious gaming, collaboration can lead to better performances than cooperative or individual playing. This can be concluded from research by Klawe and Philips [17], among others. Their research suggests that placing two persons behind a single PC had a number of positive effects. Their findings include the following:

- Sharing a computer stimulated discourse about what is being done. It is believed that this enhances learning.
- The discourse and the presence of the other learner made the learner more aware of and connected to the usual classroom environment. This is believed to enhance transfer.
- While one learner operated the input device, the other learner frequently used that time for reflection and for using other tools such as pencil and paper or a calculator.
- Learners found sharing a computer more enjoyable than playing alone.

Debriefing and group discussions

Debriefing and group discussions are tools to enhance learning with serious games that are used outside the game, but in the learning process in which the game is played. According to Lederman [18], debriefing aims at "*using the information generated during the experimental activity to facilitate learning for those who have been through the process*". Peters and Vissers [32] consider debriefing to be important because not all people that play a simulation game will be equally able to reflect on their experiences during the game and to draw conclusions from these experiences and apply them in real life. Debriefing is also considered to be useful because not all players will get in contact with all aspects of the game while they are playing, especially in multiplayer games.

Monitoring facilities

Monitoring facilities record the history of interaction in a game and give the players the opportunity to inspect this history. This allows players to look back on their own actions (and those of others) and on the reactions of the system. In this way comparison of lines of actions and thought and the formulation of hypotheses are facilitated. Especially in complex situations this should lead to a reflective mode of information processing.

Publications on the effectiveness of monitoring facilities are mostly limited to the area of simulations rather than games and De Jong and Van Joolingen [16] point out that the evidence for the effectiveness of monitoring tools in scientific discovery learning with computer simulations is not substantial enough to warrant general conclusions. Nevertheless, Leemkuil [19] states that "*monitoring facilities in some kind of form seem to be crucial for a reflective mode of information processing. When no data are available about past experiences (except for those stored in the mind of the player) it is difficult to test hypotheses and to develop new insights*".

3. Observation and measuring techniques for serious gaming

> "*Serious games, like every other tool of education, must be able to show that the necessary learning has occurred. Specifically, games that teach also need to be games that test. Fortunately, serious games can build on both the long history of traditional assessment methods and the interactive nature of video games to provide testing and proof of learning.*" [23]

Michael and Chen [23 & 24] point to the importance of some form of assessment, some form of measuring the effectiveness, of serious games. Assessment is important in both educational environments and in the corporate world. It plays an important part in modern education, whether serious game developers and teachers consider this to be appropriate or not. In order to be useable within a larger educational program, educational games will need to be assessable in order to facilitate grading and to demonstrate the effectiveness of the game as a teaching tool. In the corporate world, serious games can have an effect on the company's bottom line and, in some cases, potential liability. This means some proof of the effectiveness of serious games is required here as well. Another factor that increases the need for assessment in both areas is that serious games are a relatively new teaching tool of which the effectiveness still needs to be proven at large. As a consequence, schools and corporations may be skeptical toward the use of serious games and may require some demonstration of their usefulness.
At present, assessment of serious games, be it inside the game or before or after it, can have three functions:

- Determining for all individual learners whether they learned what they were supposed to learn, or how much they learned of it. This allows teachers or trainers to aid them in problem areas and can facilitate grading.
- Determining the effectiveness of the game. Does it teach what it's supposed to teach? How much can people learn from it? What needs to be improved?
- Contributing to research concerning the effectiveness of serious games (or specific game components) in general.

In this research, the focus will be on the second and third function and not as much on the performance of individual users, although the effectiveness of the game will be measured by assessing the performance of individual players.
This chapter will deal with a number of different methods that can be used for assessment in serious games. In section 3.1, traditional methods of assessment will be discussed, together with those used in more traditional forms of e-learning. In section 3.2 a number of challenges faced in the assessment of serious games will be mentioned, followed by an overview of what current literature has to say about assessment techniques for serious games in specific.

3.1 Assessment in traditional learning and e-learning

Developers of serious games do not have to tackle the problem of assessment on their own. In traditional learning environments, and more recently, e-learning, the problem has already been studied extensively. This has lead to a number of assessment methods that can possibly be of use for the assessment of learning with serious games too. These methods, together with issues that arise when they are applied to serious gaming, will now be discussed.

Traditional methods usable for serious game assessment
One of the traditional forms of assessment that is commonly used in and associated with serious games and e-learning is the use of multiple-choice questions. As an alternative, open ended questions may also be used for assessment and, according to Michael and Chen [24] "*other options are interviews, based around particular problems, general problem solving, surveys, or a mixture of observation, tests, and interviews*". Some of these methods of assessment can be integrated into the game itself, but this is not a necessity. A good serious game should make it easy to use these methods though.

Limited-choice questions and open-ended questions
Limited-choice questions, such as multiple-choice questions or true-or-false questions, are a common form of assessment in traditional learning environments and especially in e-learning. Limited-choice questions are easy to check for a teacher or trainer and can be checked (instantly) by a computer system as well, which is probably the most important reason for its use in e-learning. According to Mödritscher et al. [26], limited-choice questions are suited to reach lower-level learning objectives, such as recalling facts, while they are less suited for reaching higher-level objectives, such as applying or evaluating assimilated knowledge.
An alternative for limited-choice questions are open-ended questions. Open-ended questions include such things as sentence completion, formulating an own answer to a question, but also the writing of essays. These types of questions are better suited for reaching higher-level objectives.
Michael and Chen [23] also point out that multiple-choice questions are not always the best option: "*While MCQs can accurately gauge memorization and retention of a set of facts, they are hardly the best way to gauge whether the student is following a process correctly.*" In disciplines such as mathematics the process used to reach an answer (the calculation in the case of math), may give much more insight into whether the student understands the subject matter or not than a correct answer does.
Another argument against the use of limited-choice questions in serious games given by Michael and Chen [23] is that "*outside of a few isolated examples, such as Trivial Pursuit and Who Wants to be a Millionaire, they have little or nothing in common with video games.*"
Another example that could be seen as an exception to this rule is the use of "conversation trees" in many Role Playing Games (RPGs). In these games, conversation with Non-Player Characters (NPCs, characters that are controlled by the computer) takes place by presenting the players with a number of sentences to use each time their character has the opportunity to speak. Sometimes, there will only be one choice available at a certain point in the conversation, or multiple paths will lead to the same end, but there are plenty of opportunities in which choosing the right sentence can help the player in getting additional information, avoiding a fight, or deliberately picking one.

Aside from this example, which has seen it's use in serious games and e-learning already, there still is sufficient reason for Michael and Chen [23] to say the following:

> "W*hile a review of any collection of edutainment software reveals that MCQs can be easily tacked on to a video game, doing so does not take advantage of any of the features that make serious games compelling: engagement of the player, self-motivated progress through the material, and fun.*"

Interviews and observation

Interviews and observations are assessment methods that are, because of their nature, perhaps more suited for qualitative assessment of what players are able to learn from a game, although more structured forms of these methods could of course be used for quantitative approaches as well. Both interviews and observation require the presence of a teacher or trainer.

Interviews can be seen as just another way of asking limited-choice or open-ended questions, although in most cases they will focus on the latter and provide the option for less structured, non-predefined questions. Interviews can also be used to assess the opinions of the users on the use of serious games, or a particular serious game, or allow for self-assessment of what they believe they learned. Arguably, questionnaires could be used to assess these aspects as well.

Observation can be used for similar purposes, allowing the teacher or trainer to observe the interest players show in the game, retention of this interest and motivation to keep playing as the game progresses, difficulties players discuss with each other and the time they spend on certain parts of the game, among other things.

Jamornmann [15] lists five questions which he suggests the trainer or teacher should try to find an answer to while observing conversations in the chat room of an e-learning setting:

1. Who chats with whom?
2. What do they chat about?
3. Is the content related to the course?
4. Does the content lead to understand critical thinking?
5. If there are more than 3 persons, who leads the group?

These observations can also be made for face-to-face communications. These questions will help the teacher or trainer assess whether the course, or game, is effectively being used or not. Observation and interviews can easily be combined, in which case the trainer or teacher asks questions while observing. In other cases, interviews are more likely to be conducted pre- or post-game.

3.2 Assessment in serious gaming

3.2.1 Assessment challenges in serious gaming

Michael and Chen [23] discuss a number of challenges that are created by the medium of serious games itself and by its newness, which can make assessment more difficult:

- "*With less emphasis on rote memorization of facts, the assessment obtained from traditional methods may not accurately reflect the learning gained from serious games.*"
- "*Open-ended simulations can support a wide range of possible solutions. Which one is more correct?*"
- "*When teaching abstract skills such as teamwork and leadership, how do you measure learning and/or improvements?*"
- "*What is "cheating" in the context of serious games?*"

Less emphasis on rote memorization of facts
The first question is, among other things, related to the distinction between implicit, intuitive knowledge and explicit knowledge that was made in section 2.3.1. While players might have developed understandings and strategies that allow them to play a game effectively (and possibly allow them to apply them in other similar situations too), this understanding might not be reflected in the answers they give on MCQs because the knowledge is not explicit enough. As Michael and Chen [24] put it in another text:

> "*Serious games provide an opportunity to test beyond Q&A or multiple choice and may be uniquely suited to demonstrating processes, interactions, systems, causes and consequences.*"

Open-ended simulations
An example that touches on both the question of how to assess the results of an open-ended simulation and on the question of how to deal with cheating can be found in the game *Roller Coaster Tycoon*, as is pointed out by Aldrich [2]. In this game, in which players have to build and manage their own theme park, one of the metrics that is used is customer satisfaction. This customer satisfaction, however, can be increased by the players by drowning the unhappy guests. The question now is whether this behavior should be considered as the exploitation of a loophole and therefore as cheating, or whether the players using this strategy should be rewarded for the creative use of the available resources and metrics.
Even if the strategies chosen by the players are less unethical, in open-ended simulations, it might remain difficult to compare the different outcomes or the ways in which they have been reached.

Teaching abstract skills
Serious games offer the possibility to teach players abstract skills, such as teamwork and leadership. Such things as political or religious beliefs can be communicated as well. In these

kinds of cases, assessing what the player has learned may be more difficult than assessing whether he remembers a certain set of facts or not. Nevertheless, there is an entire field of study concerned with the measurement of mental capabilities, called psychometrics, and Michael and Chen [23] state that "*it has evolved over the past two centuries and has been used to measure such disparate and seemingly immeasurable capacities such as personality, individual attitudes and beliefs, academic achievement and quality of life*". This suggests that they believe the challenge of this assessment is not an obstacle that can't be overcome.

Cheating

Cheating is, in the words of Michael and Chen [23], "*a time-honoured tradition in video games*". It is common for many entertainment games to contain cheat codes that allow players to gain powerful advantages, such as invulnerability or unlimited resources. These advantages can aid players who are stuck, annoyed, in a hurry to complete a certain boring part of the game (which they might have already completed successfully once in a previous playing session), or who simply like to experience the new playing style such advantages have to offer.

Aside from multiplayer games, in which players are competing with each other and cheating is an unwanted and often even prohibited phenomenon, the use of such cheat codes is commonly accepted, although some players might consider such cheating as "weak". In serious games however, such cheating, or the exploitation of loop holes such as the one in *Roller Coaster Tycoon,* is often unwanted, because it could compromise the learning experience. Besides considering how to deal with these in-game issues, teachers and trainers will also have to think about activities outside of the game itself that may or may not be desirable, such as players consulting each other or establishing unwanted pacts and arrangements.

Pre-game, in-game and post-game assessment

While traditional classroom testing usually occurs after the presentation of the learning material, Michael and Chen [24] suggest that for serious games, both pre-game and post-game testing should take place. The reason for this is that the effectiveness of serious games is still being determined. Without measuring what the students' knowledge or abilities are both before and after playing the game, it is impossible to say how much they have increased and if anything has in fact been learned. Of course, in-game assessment can be used to assess what players learned in the parts of the game that have been completed so far as well.

3.2.2 Useful features of entertainment games for assessment

Many entertainment games already have a number of features built in that can give some indication of what a player has learned. A number of these features, mentioned by Michael and Chen [23 & 24], will now be discussed.

Game levels

Many entertainment games are divided in levels: different missions the players have to complete, different areas the players have to traverse, etcetera, arranged in a certain order.

Michael and Chen [24] state that game levels can give an indication of what players have learned, saying that:

> "*Well-designed games start out with the simplest levels, with each following level building on those game features and strategies introduced in the earlier levels. In a sense, successfully completing a level demonstrates mastery of what the game has "taught" so far.*"

Tutorials

As Michael and Chen [23] point out, every computer game has a learning objective, even those meant purely for entertainment: teaching players how to play the game. According to Michael and Chen [23], "*many game designers (whether intentionally or otherwise) build complex learning and progression into their games*". These learning environments in computer games are called "*tutorials*".

Tutorials explain to the players the basics of the user interface and the available actions and their effects in the game. Besides being an effective way of learning, a point that is argued by Gee [11] extensively, a certain form of assessment is present in tutorials as well. Players are instructed about a particular piece of the user interface or on performing a certain action and are then required to use this functionality or perform this action before the "lessons" continue. Tutorials often only introduce a limited number of game features at a time to avoid overwhelming the players. Once these have been mastered, additional features are introduced. In this sense, tutorials function in the same way as game levels. Often, one or a few tutorial levels are the starting point of the game, after which the storyline takes the player fluently to the remainder of "normal" game levels. Even in these normal levels increasing difficulty and the introduction of new features can still teach and assess new skills and strategies.

Scoring

Another form of assessment mentioned by Michael and Chen [23] is scoring. There is a large number of entertainment games that features a scoring system to assess the players performance. This scoring shows a clear similarity with the grading of tests in education. Besides being able to assess how well the players performed, scoring also allows players to determine if their chosen actions had a positive or negative effect on their score, or no effect at all. This allows them to determine what actions are relevant in the game. As with normal teaching however, some people might question the appropriateness of this focus on scores.

Assessment through game construction

Michael and Chen [23] mention another form of assessment originating from computer games, discussed by Jim Brazell, consulting analyst at the Digital Media Collaboratory (DMC) in the IC^2 Institute at the University of Texas at Austin. Brazel advocates the use of game development itself as a learning tool. He argues that a designer can only develop a game that effectively simulates a certain phenomenon or teaches information if the designer already understands this phenomenon or information himself. He also suggests that the creation of such a game can potentially lead to new knowledge and new ways of doing things through emergent behavior. Currently, this form of learning is far from common practice in the field of serious gaming, but, as Michael and Chen [23] argue: "*As the methods and tools of game development become more accessible, perhaps this new kind of "using games in education" could take its place alongside other serious games.*"

3.2.3 Serious game specific methods for assessment

Michael and Chen [23] discuss a number of more "*sophisticated*" assessment forms used in serious games, which should be effective in meeting the challenges discussed in section 3.2.1. They distinguish three main types of assessment used in serious games:

- Completion assessment: "*Did the player complete the lesson or pass the test?*"
- In-process assessment: "*How did the player choose his or her actions? Did he or she change their mind? If so, at what point? And so on.*"
- Teacher evaluation: "*Based on the observations of the student, does the teacher think the student now knows/understands the material?*"

These three types of assessment will now be discussed in more detail.

Completion assessment
Completion assessment means assessing whether a player completed the game or not. Since many serious games are simulations, completing the game can, according to Michael and Chen [23], be a first indicator that the player sufficiently understands the subject taught. They state completion assessment in serious games is equal to asking whether a student got the right answer in traditional teaching.
As Michael and Chen [23] point out, completion assessment can't be the only form of assessment by itself. Besides the possibility of cheating, there is the possibility that players simply learned how to beat the game and did not master the learning content. The accuracy of the simulation will have an effect on the usability of game skills in a real environment as well. In the view of Michael and Chen [23], "*as the pedagogy of serious games evolves, assessment in serious games will come closer to this simple ideal. In the meantime, though, more is needed*".

In-process assessment
In-process assessment concentrates on determining how the player reached a certain result. It can be compared with students having to write down their calculations at a math test instead of just their answers. In-process assessment can include the tracking of corrections. According to Michael and Chen [23], such forms of assessment are useful because "*the errors and corrections can be valuable indicators, sometimes more so than just giving the correct answer*".
Serious games offer great possibilities for tracking and logging of player behavior. In the entertainment industry, several features are already available for this, such as replay options and storing action sequences. Serious game developers have begun to facilitate the tracking of data such as how long it takes a player to complete a certain "lesson", the number of mistakes made, the number of self-corrections made, etcetera. As Michael and Chen [23] point out, modern entertainment games even incorporate abilities to adapt their behavior to the actions of the players, adjusting things like storylines, strategies and monster strength. They say that serious games could take advantage of these features.
In the future, information that is logged might be used to facilitate full in-process assessment by the game itself. In the meantime though, it can be used to assist teachers and trainers in the assessment of their students and trainees. The logged data and replays can also be very useful as a basis for debriefing and group discussions.

Teacher evaluation

Teacher evaluation is a combination of completion assessment and in-process assessment. According to Michael and Chen [23], "*despite the predictions (or fears) of some, serious games aren't going to be replacing teachers anytime soon, and probably never. To that end, serious games should include tools to assist teachers in their evaluation of students.*" Teacher evaluation can make use of detailed logging such as the in-game assessment methods that were discussed above. If properly presented, this logging helps them to evaluate how much the players have learned. "*The more data is available, the less subjective that evaluation needs to be,*" as it is said by Michael and Chen [23].

Furthermore, teacher evaluation can also include observation. Again, entertainment games already provide some useful techniques. As Michael and Chen [24] point out, there are many multiplayer computer games that include an "observer mode" for people that are not actively participating in a game. This feature allows them to observe the actions other players perform in the game environment even if they are not involved in playing the game themselves. For serious games, such an observer mode can be used by both other learners and teachers and can possibly be extended by coaching options, ranging from giving simple instructions to changing the effects of a player's decisions or introducing changes of the situation into the game environment.

4. Holodecks and other simulation environments

"Holodeck" is a word that many people will know from the science fiction series Star Trek. According to the online encyclopedia Wikipedia [44], in this series, a "Holodeck" is a room on starships in which a simulated reality is created by means of holographic projections, simulated sounds and smells and a number of less realistic devices such as replicated matter and tractor beams that simulate touchable objects and physical forces. The Holodeck is used for both recreational and training activities in the series.
Although this kind of a simulation environment would be ideal to have, there still is a large part of "fiction" in it and therefore the term Holodeck will refer to a more simplistic concept in this text, although still concerned with simulation within a closed environment. Before going into details about this concept and the way in which it is used at GPR, a quick visual impression and short description of what such a Holodeck might look like shall be given, accompanied by a number of examples of similar environments that have been set up by other organizations. In section 4.1, the Holodeck environment that has been used at the Belastingdienst will be dealt with, followed by the discussion of a number of similar environments in section 4.2: The T-Xchange Cell and simulation tools developed at E-Semble. The exact concept of a Holodeck as it was established at GPR will be discussed in the next chapter.

4.1 The Holodeck at the Belastingdienst

The Holodeck at the Belastingdienst was a room that was used for so-called Proof of Concepts (PoCs) during the development process of a new information system for the processing of "toeslagen". During a number of these PoC sessions, a group of end users was provided with information about the new system and the progress of its development, was given the opportunity to perform a number of tasks with the system to experience how the functionality of the system that had been completed so far worked and was then guided in a process of feedback and reflection on these experiences.
The Holodeck environment that was set up to support these PoC sessions is illustrated in Figure 4.1. It contained a projection screen for presentations, a number of work stations with PCs that allowed users to sit down and experiment with the new information system, a whiteboard and flip-over to facilitate reflection and feedback sessions and a number of pictures and digrams that illustrated such things as the planning of PoC sessions and the functionality they would cover and a process diagram illustrating the way in which the new system would support the processing of "toeslagen".
This environment provided the group of end-users with the opportunity to familiarize themselves with the way the new information system would function and allowed them to determine what implications this system would have on their work process, whether such a process was feasible and what changes could or should be made to the system or the surrounding work process in order to arrive at an optimal solution.

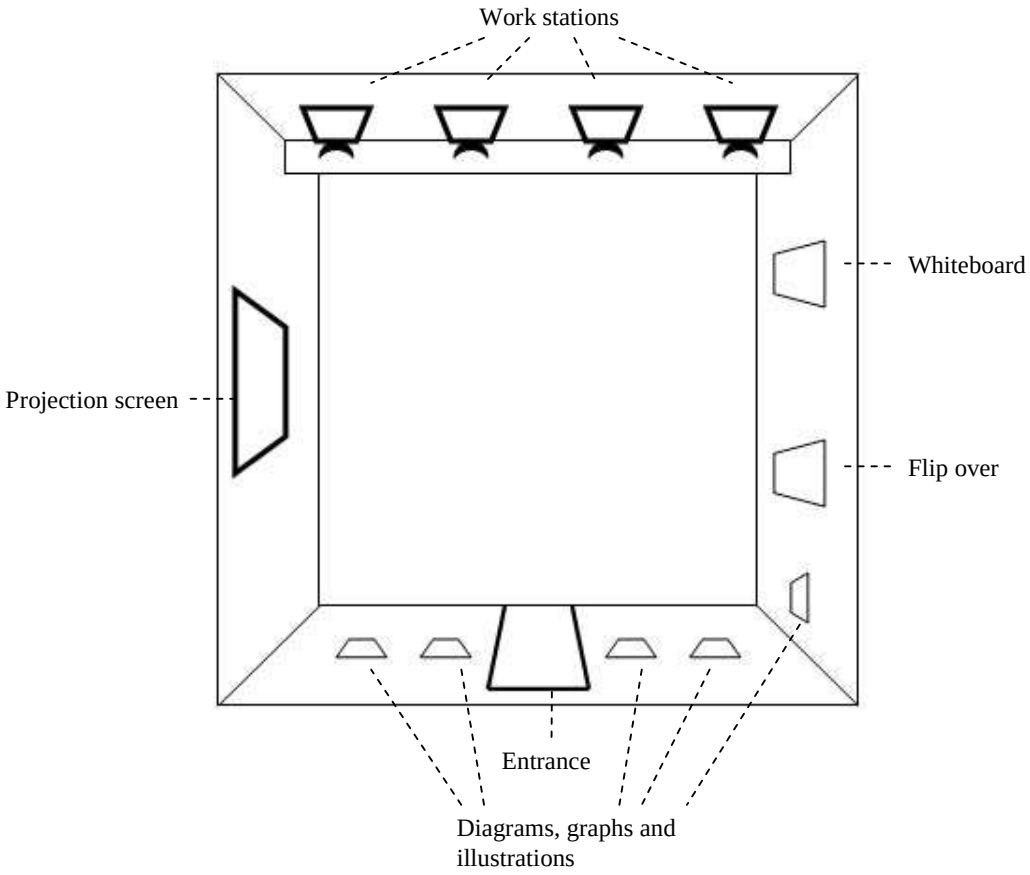

Figure 4.1 - Layout of the Holodeck and its various tools as it was used during PoCs at the Belastingdienst.

4.2 Similar environments

Besides the Holodeck concept that was developed at GPR, a number of simulation environments may be found that show considerable similarities with this idea. To further illustrate the idea of what a Holodeck might be, a number of these environments will now be discussed briefly, supported by some images to give a visual impression.

4.2.1 T-Xchange

T-Xchange [39] is an initiative of Thales Nederland B.V. and the University of Twente. Together, they have set up a high-tech simulation environment with rich tools for visualization, of which some pictures can be found in Figure 4.2 and 4.3.
The T-Xchange Cell is used to support decision-making processes focused on designing solutions for complex problems. This is done by bringing together a number of experts and stakeholders in an environment in which computer simulation (T-Xchange uses the term serious gaming) is used as a tool for visualization and as a way of providing a simulated "reality", including behavioral rules, in which people can safely experiment with different kinds of solutions and discover their implications. Among other things, T-Xchange has been used to explore the possible implications the expansions of a sports stadium could have on traffic, to design a new residential district and as a tool for product design.

Figure 4.2 – The T-Xchange Cell in Twente, a high tech simulation environment. [39]

Figure 4.3 – Details of the T-Xchange Cell. [40]

4.2.2 E-Semble

E-Semble [10] is a Dutch organization based in Delft, which designs and develops tools for training and education of safety and security professionals. E-Semble has developed a number of simulation tools, such as Diabolo VR, which uses serious gaming in a 3D computer simulated environment, such as the one in Figure 4.4, for incident management training. The focus of Diabolo VR is on this digital world, but there are some elements that have been added to the environment in which the game is played that make it more then just a serious game.
Often, the game world is projected on a large format in front of the player, rather than being displayed on a regular monitor. This is a small step in the direction of virtual reality, since the game world, which is seen from a first-person perspective (through the eyes of the character the player is controlling), is now displayed at a more proportional size, increasing the realism of the experience. Furthermore, communication with other players occurs through regular communication means such as radios, taking a part of the game outside of the control of the computer program and into the real world environment of the player, which may also increase realism. A picture of this can be found in Figure 4.5. Besides this, the scenario of the simulated disaster or emergency situation is not pre-fixed, but can be manipulated by a game master controlling his own computer, which is linked to that of the players.

Figure 4.4 – One of the virtual simulations of disasters developed by E-Semble. [10]

Figure 4.5 – E-Semble uses large projections and the use of regular communication means to enhance the game experience. [10]

4.2.3 Virtual reality

Besides the examples that have been discussed so far it is likely there are a number of other simulation environments that have similar characteristics and serve similar purposes. Furthermore, another kind of simulation environment that has not yet been discussed but is strongly related to the term “Holodeck” is the virtual reality environment.

Virtual reality is a concept that has not yet been dealt with in this discussion, but is strongly related to the original concept of a Holodeck from Star Trek. Virtual reality usually refers to technology that is used to submerge a person fully in a virtual environment. Mostly this is limited to visual experiences, such as head mounted displays or stereoscopic displays (which create a 3D illusion), but there are also numerous environments that provide other sensory information, such as sound or haptic feedback. Figure 4.6 shows one of the more impressive examples of virtual reality technology. An interesting discussion of how current and near-future technology might be used to provide the different kinds of sensory feedback present in the Star Trek Holodecks has been written by Rhodes [35].

Figure 4.6 – The VirtuSphere, a device that allows for free movement in all directions during a virtual reality experience. [42]

4.3 Common characteristics

There are a number of similarities that can be found in the examples of simulation environments that have been discussed so far. In this section, a number of common characteristics that can be identified will be discussed. These are:

- Simulation
- Interaction
- Group activity and collaboration
- Use of IT

Simulation
Every environment that has been discussed in this chapter offers some kind of simulation to its participants: an office environment with access to a future “toeslagen” system, a virtual representation of a product, or a disaster scenario that might occur. Such a simulation may be provided either by offering the tools that may present a virtual simulation to the participants in an environment, or by using the environment as part of the simulation itself. This may range from a simple office environment, such as the one used for PoCs at the Belastingdienst to more complex environments, such as a burning building from which people need to be rescued.

Interaction
Every environment that has been discussed above allows for interaction. Participants can change (parts of) the simulation with their actions, whether they play a part in this simulation or manipulate it from the outside.

Group activity and collaboration
All the environments discussed above can be used by a group of people, and most of them are specifically designed to be used by a group of people. They may collaborate in these environments in two ways: First of all, they may collaborate to reach a common goal in the simulation, such as safety and security personnel that is being trained to work together in an emergency situation. Secondly, they may collaborate by experimenting with a simulation and evaluating and discussing their experiences to develop a solution to a complex problem, as it is done at T-Xchange. Experimentation that is done within the first form of collaboration, working together to reach a common goal, may also be used to support the second purpose of finding and optimizing solutions.

Use of IT
All environments that have been discussed so far make use of information technology, either as a means to offer a virtual simulation to participants, as a means of providing them with information for introduction and reflection purposes, or as a tool that is present in the environment that is being simulated (like the workstations at the Holodeck at the Belastingdienst). Although the use of IT is not a necessity in a simulation environment it will almost always be able to support one of these three purposes. For this reason, the next section of this text will deal with the IT hardware that may be used in a Holodeck or similar environment.

4.4 Required hardware

A Holodeck or a similar simulation environment can make use of a wide variety of tools and hardware to offer a simulation experience to its users. These may range from high-tech, virtual reality kind of tools, such as those used in the T-Xchange Cell, to more modest hardware equipment such as a beamer or a number of PCs.
What kind of hardware is required depends on the purposes for which a Holodeck will be used and on the content of the simulation. The available budget may also play an important role for many organizations. Expensive, high-tech solutions are not always necessary or better however. The most important thing is to create an illusion that sends out the right impression to the Holodeck participants, engaging them in whatever is being simulated and their role in this. If a few simple tools can create such an impression, this is good enough, or even better. If some more advanced tools can enhance the experience, these might be worth considering, or even be necessary to allow a Holodeck to be used in an optimal way.

A list of required hardware in a Holodeck that uses IT as a tool or as a means of delivering a virtual simulation can be established, regardless of whether such tools are high-tech or low-tech. This hardware will be discussed in its general form in the text below and in Appendix A, a number of concrete hardware tools and their estimated prices can be found.

Interaction facilities
When a Holodeck offers a virtual simulation or provides an information system as a tool, participants should be able to interact with this system, which means one or more “work stations” have to be present. Such a work station should consist of input devices, a monitor (and possibly other output devices) and a computer for processing.
Participants may use such a work station individually, in small groups, or one of the participants may interact with a system while the group influences this interaction through face-to-face discussion.

One or more central displays
Next to individual workstations with an individual display, there may also be a need for one or more larger, central displays which can be seen by the entire group of participants. Such a display may be used during presentations which might be held as an introduction, but may also present a group of participants with the same view of a virtual world or object, which may then be discussed. It may also be used to offer any visual aid that can be used during reflection and feedback sessions. This may be in the form of presentations with points of interest, but may also include replays of the behavior of participants during their experimentation or an overview of the results of such experimentation (performance).
Such a large central display may be provided by a beamer and projection screen or a large TV monitor, but may also include larger or technically more advanced displays such as the ones that are used at T-Xchange.

Reflection facilities
Both environments that are used for developing a solution to a complex problem and environments that are used for training or education should allow the participants and facilitators to discuss and reflect on the experiences gained during a simulation. The environment should provide the tools for this process. Such tools may be as simple as a

whiteboard, a flip-over, or both, together with a couple of markers. As was already mentioned above, a central display may also be used to provide visual guidance to such a process.
In technically more advanced settings, videotaping might be used to capture the behavior of the participants within the environment so it may be evaluated later on. Any interaction with a digital simulation or an information system that is used as a tool may be tracked for later reflection by detailed logging and playback functionalities.

Network facilities
A network may have to be set up in the Holodeck environment if different PCs have to be linked to each other during a simulation, or if the actions and results of individual players need to be logged and stored centrally.
Any local network, such as a router and a few Ethernet cables may suffice to provide such a network, or a network that is already available can be used. Security precautions and access restrictions should be taken into account when such a network is set up as well.

Furniture and decorations
Although furniture and decorations fall outside the scope of IT hardware they can be of great importance in a Holodeck. First of all, furniture may have a practical value. The amount and type of desks, chairs, tables, tools such as pen and paper and their arrangement in a Holodeck environment may have a strong influence on the interactions that can be performed within such an environment. Furthermore, furniture and further decorations may also influence participants on an emotional level. They can be used to simulate a certain environment, like an office, but may also be used to submerge people in an environment that is different from their normal work environment, making it easier to let go of their old thinking patters. The Holodeck used for PoCs at the Belastingdienst for example, had been decorated in IKEA fashion with a number of work lamps and a small rug, For both practical and emotional reasons, the physical arrangement of a Holodeck environment should be carefully considered.

5. The Holodeck concept

The concept of a Holodeck was invented by Martin de Haas, a business consultant at GPR (although it was an idea of his colleague John Christiaanse to assign the name "Holodeck" to this concept). De Haas describes a Holodeck as a work environment in which people can experience and experiment with a simulation of a certain "reality". In the case of GPR, this comes down to an environment in which people can work with a simulation of a process that is supported by an information system. Users can experiment with a simulation or prototype of this information system, often in the role of an end-user, to experiment with the functioning of the system and to experience how it supports them in doing their work. The Holodeck that was developed for use during the PoCs for the Belastingdienst for instance, allows a group of people to perform a number of tasks with the new system for "toeslagen" on a number of PCs that have been placed in the Holodeck environment. The room also contains tools for presentations and feedback sessions, so participants can be provided with the necessary background information before experimenting with the system and can reflect on their experiences and provide feedback afterwards.
The concept of a Holodeck as it was established at GPR will now be discussed in more detail, starting with a discussion of the purposes for which a Holodeck might be used in section 5.1, followed by an explanation of how it may be used for these purposes and how these purposes are interlinked in section 5.2. In section 5.3 the setup of the Holodeck environment and a Holodeck session will be examined and in section 5.4 a general definition of the term "Holodeck" shall be given based on these previous discussions.

5.1 Purposes of a Holodeck

The idea of a Holodeck originated from the observation that during the development of IT supported solutions, most of the time seems to be invested in making explicit what a system should do. The people involved may have trouble imagining certain ideas for themselves, have trouble thinking in abstract concepts that are often used during an IT design process, or have different interpretations of these concepts. This means they might be talking about different things without realizing they are, because the terms and models they are using are the same. It was believed that by taking similar, existing applications that contain interesting (parts of) possible solutions or working prototypes of possible future applications, it would become a lot easier to make things more explicit and ensure that everyone is talking about the same concepts and interprets them in the same way. This way, miscommunication could be avoided and people who have difficulty with abstract concepts, such as certain end users might have, could also be involved in the development process more effectively. If people can look at and experiment with explicit (prototypes or simulations of) applications, they can determine what works well in these examples, how one could work with such an application, what could be improved and what is still missing. In order to determine these things, a setting will have to be created in which the situation in which the application is actually used can be simulated. This is where the idea for a Holodeck came in. In abstract terms, the purpose of a Holodeck can be defined as follows:

A Holodeck is intended to provide an experience to a group of participants. It lets them experience a certain "reality" (situation, process, environment, etcetera) and interact within this reality. To make such an experience as rich as possible, a Holodeck seeks to submerge its

participants fully in this experience, mentally, emotionally and physically. It seeks to create a simulation that is as realistic, detailed, open and engaging as possible. Such an experience can then be used to understand, analyze and possibly change and improve this "reality".

This "metagoal" of submerging participants in an experience of a certain "reality", be it an existing one or an envisioned one, can then be used for a number of more specific purposes. The Holodeck may be used for other purposes than that of requirements engineering from which it originated. Neither is its usefulness limited to the domain of IT. It may be used to find a solution to a complex problem in the form of any kind of process organization or form of collaboration, of which a work process that is supported by an information system is just a single form. In an interview with De Haas, of which the full version can be found in Appendix B, the following purposes that a Holodeck might serve were identified, of which only the first is IT specific:

1. Making the use of applications transparent
2. Supporting strategical decision making
3. Serving as a design instrument
4. Supporting sales
5. Supporting requirements definition
6. Optimizing processes
7. Assigning value
8. Creating a business case
9. Serving as a training instrument
10. Supporting change management

Making the use of applications transparent
Another observation of De Haas was that administrators, responsible for managing an information system and making changes to this system when necessary, often have a very poor idea of what these applications are used for. By simulating a work setting with a Holodeck they can quickly get an explicit idea of what these systems are used for and what they should be able to do, enabling them to aid in the process of finding solutions to problems that arise.

Supporting strategic decision making
Strategic decision making can be supported by visualizing alternative directions for solutions. A Holodeck is intended for use in situations where the nature of the solution to a problem is unknown and different directions will have to be explored and valuated before one of these directions can be further explored.
By representing alternatives in an explicit way, by demonstrating and letting people experiment with existing solutions of other organizations to similar problems or simulations of promising variations on certain solutions, people will be able to get a quick and clear overview of the possibilities and the advantages and disadvantages of the different solutions.

Serving as a design instrument
Similar to the use of prototyping in the design of information systems, a Holodeck can be used to let people experiment with early versions of a solution, allowing them to see what is or is not working and what should be improved in the next iteration. In contradiction to

prototyping, a Holodeck does not just offer an information system to experiment with, but allows its participants to experiment with all kind of solutions, processes and collaborations not necessarily including the use of IT.

Supporting sales
The Holodeck can be a tool for the support of sales and marketing in much the same way as it can be a tool for the support of strategic decision making. It can be used to demonstrate alternative directions for solutions and determine feasible ones.

Supporting requirements definition
By letting people work with a simulation at an early stage, they will run into problems that will need to be dealt with in the future solution and may discover other useful features that are desirable. An explicit simulation will allow people to determine what is actually needed.

Optimizing processes
A Holodeck can be used to let people experiment with a simulation of a process and let them determine the best way to work with the tools that are available in the simulation. Areas that leave room for improvements can also be identified this way.

Assigning value
Assigning value to an IT application is often a difficult issue. According to De Haas, current techniques, such as measuring the number of functionalities, do not measure value in the right way. Having certain functionalities in a system does not mean that they are useful or add value. It says more about the costs to develop such functionalities than it says about the benefits. A Holodeck may be used to give a better indication.
By simulating different setups of a process in a Holodeck environment, these setups can be compared to each other. People can experiment with certain steps in these processes to discover how these steps can be performed in a better or more efficient way and can determine what value these steps add for the customer. This way, a Holodeck can be used for the allocation of value to IT components.

Creating a business case
By developing a small scale, but fully functional prototype within a Holodeck environment it becomes easier to determine the benefits and costs of implementing that system on a larger scale. For example, if an application has been developed that can fully support the work of one single employee working at a call center, it becomes easier to determine the benefits and costs of implementing such an application for all employees at this call center.

Serving as a training instrument
A Holodeck is meant to provide a realistic simulation of a solution and to allow people to interact with it in the way it should be used by its end-users. As such, it may also be used to provide these end-users with a clear image of what the solution looks like and how it functions and will allow for the simulation of tasks they would have to perform with it in reality, allowing them to practice these tasks in an environment in which mistakes can safely

be made. Therefore, the Holodeck may be very suitable as a training environment once a simulation is sufficiently complete and finalized. Possibly, some adaptations will have to be made to a simulation so it may be used in an optimal way for this purpose, but a Holodeck that has been used for other purposes such as design is still likely to provide a good basis.

Supporting change management

A Holodeck can also be used to create support and acceptance for a new solution within the community of users. It can be used to let users experience the future solution themselves and can be used for additional demonstrations and presentations. This way, people get a clear idea of what the changes will look like and get the idea that they are given enough opportunity for input and feedback.

5. 2 Use of the Holodeck

Some of the purposes described above can be related to each other, such as a process of requirements specification that is followed by a design process, supporting each other to reach the overall goal of finding a solution to a complex problem. A Holodeck can support such a sequence in which it is used for different purposes during a change process. How a Holodeck might be used in this way is illustrated in Figure 5.1 and will be explained further below:

1. The existing "reality", the current situation, is analyzed to identify the problems that exist in this situation and the changes that are desired. This analysis may be based on real world experiences, or a Holodeck simulation may be developed in which people can experiment with the current situations to identify these problems and desired changes.
   This step may support the goal of supporting *requirements definition* mentioned earlier.
2. A number of alternative directions for solutions are determined and evaluated. A Holodeck can be used to present a number of alternatives, which might consist of solutions other organizations use for similar problems, or demos of variations on existing solutions, after which the value of these alternatives can be compared.
   This step may support the goal of *supporting strategic decision making* or *supporting sales* mentioned earlier.
3. A Holodeck is created (or adapted) in such a way that it can be used for simulating the reality concerned and allows one to change this simulated reality by implementing (partial) solutions into it. The Holodeck should be able to simulate the new kinds of "realities" that may be expected based on the chosen solution direction.
4. Based on the chosen solution direction, a number of tools are identified that may be necessary to reach such a solution, such as certain functionalities in an information system that could support the process. A distinction is made between tools of which it is sure that they are necessary and tools which might be necessary in order to reach a solution. Note that such a process is necessary because the exact nature of a solution is unknown for the problems for which a Holodeck is used.
5. One or more tools that were identified as being necessary are developed.
6. The tools that have been developed are integrated into the Holodeck reality, after which participants can experiment with this new reality and evaluate it. This way, participants can determine what implications the use of these tools has on working within the simulated reality and may identify new problems and tools that are required to solve these problems or tools that may improve the current situation. Because of this, step 4, 5 and 6 may be repeated a number of times to gradually improve the situation until a situation is reached that is considered adequate.
   This process may support the goal of *supporting design, optimizing processes* or *assigning value*. If the Holodeck reality that has been developed is a small scale version of the actual reality, but has reached completion on this smaller scale, it may be used to support the goal of *developing a business case* as well.
7. Once the development of new tools has led to an improved situation in the Holodeck reality, this solution may be mapped to the real world. This can be done as soon as a tool has been integrated and successfully applied in the Holodeck reality, or once a complete solution has been reached in the Holodeck reality through a number of iterations.

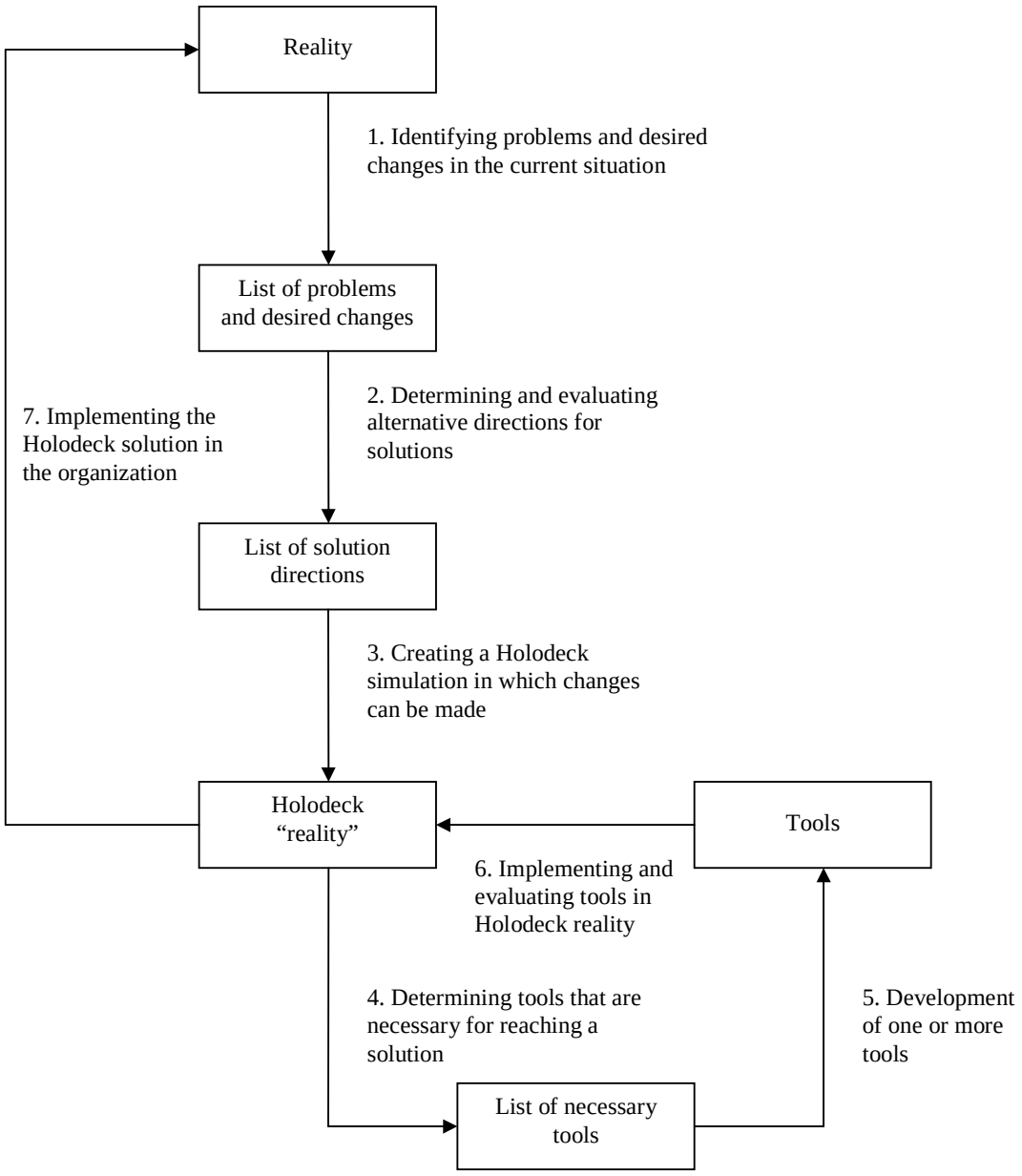

Figure 5.1 – The way in which a Holodeck may be used to support various goals during a process of adaptation or change.

Once a final solution exists that can be experienced on the Holodeck, this environment may be usable for other purposes as well. It may be used to inform end-users of what changes they can be expecting, allowing them to get a clear picture of what these changes will look like, or the environment may be used for training end-users, teaching them the new way of working. Of course, some changes to the content of the Holodeck experience may be required for this, but an environment in which a new process can be explained, demonstrated and in which people can work with it themselves does not seem to be a bad place for this.

5.3 Setup of the Holodeck environment and a Holodeck session

This section will present a general format for the setup of a "Holodeck session" and the physical layout of a Holodeck environment. This discussion is based on the Holodeck that was used during PoCs at the Belastingdienst, illustrated in Figure 5.2, but presents a general setup for any Holodeck session and illustrates how the Holodeck environment may support such a session.

5.3.1 The four phases of a Holodeck session and their support

The Holodeck experience can be divided into four phases and a separate wall with appropriate tools is available for each of these phases within the Holodeck environment. These four phases are:

1. Introduction phase
2. Experience phase
3. Reflection and abstraction phase
4. Implications phase

1. Introduction phase
The first part of the Holodeck experience consists of an introduction. In this introduction, participants can be informed of the goals and setup of the session and can be presented with the necessary background information, information about the progress that has been made since the last session, or information about the progress of the overall project.
The Holodeck environment supports such introductions with a large monitor or projection screen, which allows for presentations and the display of video material.

2. Experience phase
Once the participants have been provided with the necessary information in the introduction phase, they get the opportunity to interact with (a prototype or partly completed version of) the information system themselves. To make this possible, a number of work spaces, each of which contains a PC, have been set up against a second wall of the Holodeck environment. Here, participants can experience how the system behaves, how they can work with this system, what works well and what could be improved and what the system is still missing. They can, for instance, perform a number of tasks with the system that end-users normally would have to perform during their work, in which each task deals with other relevant aspects. This process can be guided by a simple paper walkthrough, by the rules and story of a serious game, or participants can be left free to try out different things themselves.
Although this setting contains a number of desks with PCs as the main tools for simulation, other kinds of tools could be used to simulate different kinds of "realities" as well.

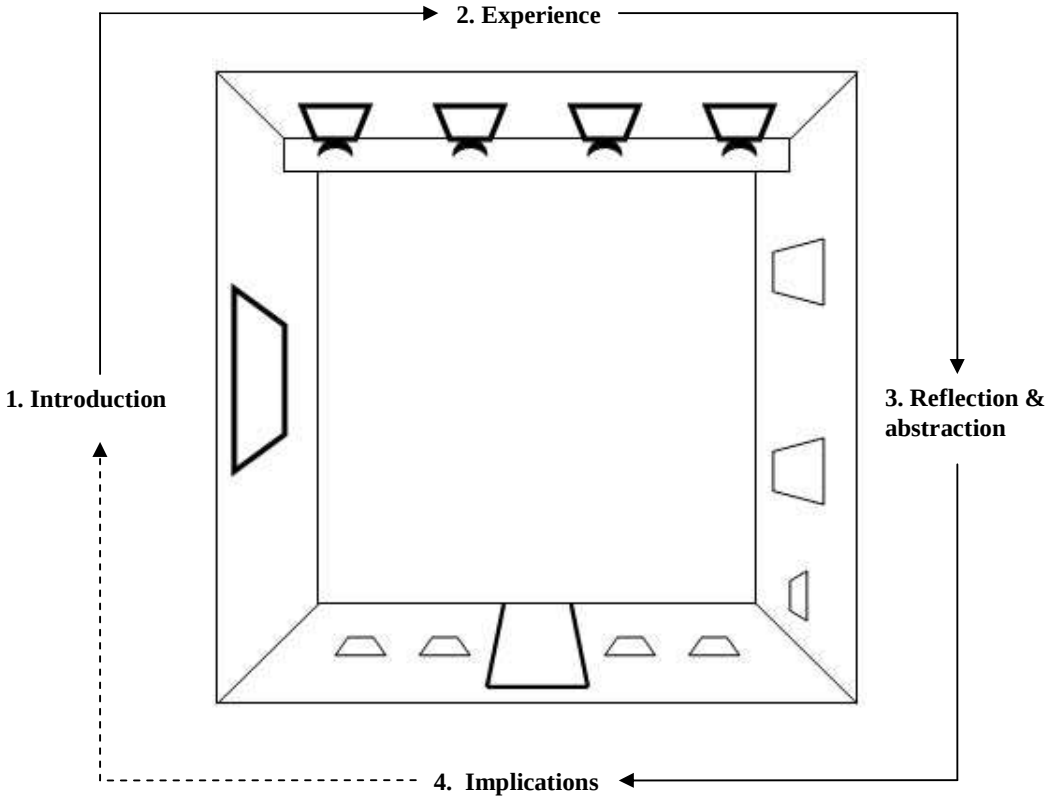

Figure 5.2 - Layout of the Holodeck as it was used during PoCs at the Belastingdienst, displaying the different phases of a Holodeck session.

3. Reflection and abstraction
During the reflection and abstraction phase, participants get the opportunity to provide feedback about their experiences during the previous phase. During group discussions, they get the opportunity to reflect on these experiences and will be guided in translating these discussions to a more abstract level, linking the particular experience to the more general process of which it is an example. Together, they can discuss what went well and what not, what improvements could or should be made and what tools or functionalities of these tools are still missing.
The Holodeck environment provides tools for facilitating such discussions in the form of a whiteboard and a flip-over. Process diagrams may be hung on the wall to visualize the abstraction process. The discussions should be guided by a facilitator.

4. Implications
Finally, the experiences and derived abstractions can be placed back into a larger context to consider their implications for this context. The use of an information system as it has currently been tested may require certain other tasks to be performed manually, or may be able to automate certain steps in a work process. Such implications for the work process and the organization have to be identified. Identification of missing tools and functionalities may also have implications for the planning of the development process, which may have to be revised.

The Holodeck environment may provide charts and pictures which may be referred to during this process, such as a timeline of the planning or photos symbolizing the stakeholders for which implications will have to be considered.

The process that was described above can be repeated in a next Holodeck session once a number of changes have been made based on the outcome of this session, or it can be used to present participants with a number of alternative “realities” during a single session, in which case each cycle deals with another reality.

5.3.2 Required expertise

To support these four phases of a Holodeck session, a number of experts are needed. Five different expert domains were identified during the interview with De Haas:

- *Domain expert*: Someone who has full knowledge of the problem domain and knows exactly what should be achieved by the new way of working. This expert is of importance during the introduction phase and may offer advice and guidance during the experience phase.
- *Expert on tools*: Someone who has full knowledge of the tools that are used to support a solution, such as an information system. This expert is of importance during the experience phase.
- *Expert on facilitating reflection and group discussions*: Someone who knows how to facilitate group discussions and feedback sessions and can structure and guide these processes. This expert is of importance during the reflection and abstraction phase and the implications phase. The domain expert and expert on tools should also be available during the reflection and abstraction phase, to receive feedback and deal with questions that touch on details within their areas of expertise.
- *Project manager*: Someone who can position the content of the Holodeck session in the overall (planning of) the change process. This expert may provide such information during the introduction phase or implications phase.
- *Simulation/serious game developer*: Someone who can develop a simulation or serious game that can be used during the experience phase. It requires expertise on how to offer content, rather than what to offer.

These experts do not have to be individual people, but represent the required areas of expertise. A domain expert might be an excellent facilitator as well and a serious game may be developed by a team of game designers rather than one.

5.4 Definition of a Holodeck

Earlier in this text, a Holodeck was described as a work environment in which people can experience and experiment with a simulation of a certain "reality". Now the concept of a Holodeck has been illustrated in more detail, a more formal definition of the term "Holodeck" can be given. The description above contains four important elements that may help in formulating such a definition:

- Environment
- "Reality"
- Simulation
- Experiment

Environment
A Holodeck consists in a physical environment, such as a room. This environment may be a part of the "reality" that is simulated, or it may contain tools for creating such a simulation, such as a monitor for displaying virtual environments.
The Holodeck environment is clearly separated from the outside world. This means that participants within the Holodeck environment are clearly distinguishable as a group because of their presence within this environment and that there is no unwanted interaction with the outside world.

Reality
"Reality", as it is used here, refers to anything that exists or could exist in the real world. This includes both physical existence and the existence of rules, behaviors, arrangements, etcetera. It may be a certain object for example, but also its physical properties and the laws of physics that operate on it can be considered as a part of the reality that is simulated in a Holodeck. Work settings, process organizations and actions performed during these processes are other examples of realities. Any interactions that participants perform within their "role" in this reality will also become a part of it.
The realities simulated in a Holodeck can be both existing realities and realities that could exist in a hypothetical sense.

Simulation
According to Wikipedia [46], "*simulation is the imitation of some real thing, state of affairs, or process*", in other words, simulation is the imitation of some kind of "reality". This simulation may not be an exact imitation of this reality, but may be limited to an imitation of certain key characteristics or behaviors. According to De Haas, in a Holodeck it may be important to simulate other, "trivial" details as well to engage participants in a fantasy, or simulated reality, that is as realistic and complete as possible, also on an emotional level. Furthermore, simulation means actions performed with or within this simulation do not affect the outside, "real" world.

Experiment
Experiment refers to the fact that, during a Holodeck session, participants get the chance to interact with(in) the simulated reality. They get the chance to perform certain actions and make certain changes and then experience the effects of these actions.
Experimentation does not have to be completely free, but may refer to guided interaction as well in the concept of a Holodeck, such as trainees learning to perform a number of tasks with an information system by following a manual. Active involvement and interaction with(in) a simulated reality to experience its behavior is the key issue in the concept of experimentation in a Holodeck environment.

Now the meaning of these different elements has been established, they can be combined with the purposes of a Holodeck that were discussed in section 5.1 to arrive at the following definition of a Holodeck:

A Holodeck is an environment in which realities of a complex nature can be simulated and a group of people can interact and experiment with or within this simulation, with the primary purpose of finding a solution of an unknown nature to a complex problem.

Although a Holodeck can take a number of different forms and may be used as a tool for a number of purposes, including secondary purposes such as training, this is the definition of a Holodeck on which the discussions in the remainder of this text shall be based. Since GPR is a company primarily concerned with IT, some parts of this text will focus on processes involving the use of information systems, but these parts of the discussion can be translated to other kinds of processes and solutions as well.

6. Serious gaming and the Holodeck

When looking at the purposes of serious gaming and the Holodeck concept and the ways in which they support these purposes, there clearly are a number of similarities: simulation, experimentation and interaction and engaging people in an alternative reality. At GPR, serious gaming was seen as a tool that might be used during the *experience phase* of a Holodeck session, as discussed in section 5.3.1. At the same time, the idea of a Holodeck environment as a place where the fantasy that is created in a serious game might reach beyond the edges of a computer monitor, or where gaming could immediately be combined with an appropriate introduction and reflective discussion, seems to be a useful addition to the concept of serious gaming.
In this chapter, the concepts of serious gaming and the Holodeck will be compared to discover ways in which they may support each other and ways in which they differ. In section 6.1, the added value a Holodeck might provide to serious gaming will be discusses, whereas in section 6.2, the discussion will be reversed and the added value serious gaming might provide to a Holodeck will be examined. Finally, in section 6.3, the discussion will focus on the effects a Holodeck may have on the usability of assessment methods for serious games that were discussed in Chapter 3. Before the discussion on these topics is started however, it is useful to make a distinction between the dynamic and static use of a Holodeck and the ways in which it may provide a simulation.

Dynamic and static use of a Holodeck
A Holodeck may be used for a number of different purposes and because of this, the way in which a Holodeck is used may also differ. The following distinction between two ways of using a Holodeck may be made:

- *Dynamic use of the Holodeck*: This is the way in which a Holodeck is used for purposes such as design and optimizing processes. The Holodeck is subject to change, since the “reality” is constantly evaluated and then adapted.
- *Static use of the Holodeck*: This is the way in which a Holodeck is used for purposes such as training. The Holodeck lets participants experience a certain static “reality” instead of constantly seeking to change it.

The distinction between these ways of using a Holodeck may have important implications for the usability of serious gaming and serious game elements in the environment. These implications will be discussed in section 6.2.

Ways of providing a simulation
A Holodeck may also provide a simulation in different ways:

- The environment may offer the tools to present a virtual simulation to the participants and the tools to let them interact with it. An example of this is the way in which the T-Xchange Cell is used.
- The environment may be a part of the simulation, imitating the environment in which participants might be working in the role they play within this simulation. An example of this is the Holodeck that was used during the PoCs at the Belastingdienst, which provided the illusion of a simple office environment.

Besides any implications this distinction might have for the arrangement of a Holodeck environment, it also has important implications for the experience within this environment. If the environment is used as a part of the simulation, participants and all of their behavior within this environment will become a part of the simulation as well.
Note that a combination of these two ways of using a Holodeck is also possible. An example of such a combination can be found in Diabolo VR. Although the disaster area is a virtual one and the participants interact with it by means of a joystick, interaction with other participants occurs outside of the virtual world by means of radio contact. The use of a radio and the communication with others are now a part of the simulation that takes place within the real world environment. These different forms of using a Holodeck to provide a simulation may have several implications, which will be dealt with in the discussions in the next sections.

6.1 Added value of a Holodeck for serious gaming

This section will deal with a number of ways in which a Holodeck may provide added value to serious gaming. Particularly the use of a Holodeck itself as a game environment may provide interesting opportunities.

6.1.1 Openness

Although IT may be a suitable tool for the creation of very useful simulations, such simulations always share one characteristic that could be a disadvantage: in every serious game or other virtual simulation, the behavior of the game world and the possibilities for interaction with(in) this game world have to be programmed and hence predefined. Even in so-called open-ended computer simulations, the actions with which players can manipulate the game world have been determined in advance and are a subset of what such people could do in a real world environment. Furthermore, the objects that can be placed in a game world will only consist of those that have been modeled in advance and their behavioral properties (e.g. breakability, flammability) will only be present if they have been programmed into the simulation.
Simulation in a real world environment is not limited by many of these restrictions and may therefore be considered to be more “open”. To illustrate the differences between real world simulation and virtual simulation further, the “openness” of a simulation may be separated into the openness of the game world itself and the openness of the way in which participants may interact with(in) such a game world (rules).
An open game world, or open simulation, means that the game world can be manipulated in any way; there is no limited amount of actions to choose from. There are also no restrictions on the elements from which a game world may be composed or on the behavior of the game world (e.g. physical forces, economic forces). In closed simulation, the game world is created of predefined object and the properties of these objects and the behavior of the game world will only include a subsection of those that would exist in the real world.
Open rules means that the players can use a simulation in any way they want, determining for themselves how to organize their behavior, while in a simulation with closed rules, there are restrictions on the way in which the players should behave and how they may use the

possibilities for interaction the game world offers. Work is done according to a predefined process specification, or a game is played according to a fixed set of rules with fixed goals. By placing the openness of the simulation next to the openness of rules four different combinations can be identified. These combinations and the places where several digital and real life simulations belong are illustrated in Figure 6.1.
Open rules, closed rules and open and closed simulation may all have their advantages and disadvantages, depending on the purpose for which a Holodeck is used and the goals of a specific Holodeck session. These advantages and disadvantages will now be dealt with.

Open simulation vs. closed simulation
If a simulation is not being restricted by what has been programmed in advance, several unexpected discoveries may be made during the use of such a simulation environment. First of all, the simulated environment itself may behave in unexpected ways, or seemingly irrelevant aspects may turn out to be relevant. A firefighter, for instance, may be perfectly capable of handling himself in a virtual simulation of an emergency situation, but in a real world simulation, he may suddenly find that he cannot move at same constant speed because he gets tired after a couple of minutes. He might also trip over one of the hoses during a real life simulation, something that is even harder to predict. On the other hand, the player may also discover that a staircase that has partially collapsed is still sufficiently useable for an evacuation.
“Open” simulation may also lead to unexpected behavior and interaction of participants. If the interactions that are required to perform this little trick have not been programmed into a computer simulation, using it will not be an option.
On the other hand, the “closed” nature of computer simulations does not necessarily have to be a bad thing. Creating a computer simulation of a certain reality is a matter of abstraction and if this abstraction process is performed correctly, all relevant aspects of this reality will be included, while irrelevant details that might be distracting are left out. Such simplification may be useful in learning environments, while open simulation may be more useful for certain Holodecks that are used in a dynamic way. Open simulation may only be reached in a real life game world.

Open rules vs. closed rules
The freedom of interaction players get while playing a game or during a Holodeck experience may be limited in various ways for various reasons. A game may have a fixed story with a fixed sequence of events, while the steps of a work process may have to be performed in a certain order or certain way to ensure compatibility with other processes. There may also be “game rules”, like the ones you will find in a board game, which may restrict the players in the actions they can perform.
Closed rules are particularly useful in static environment, where a fixed storyline may provide a clear example of what the participants are meant to experience and ensure that the participants encounter all relevant aspects during an experience. A fixed process description may be needed in training situations to learn participants how to perform a certain task.
Imposing rules on the behavior of participants in a dynamic environment may also be very useful on the other hand. For instance, by restricting participants to communicate only with person a on their left, they may find that there is no effective way to organize a process because communication with person b on their right is a crucial element.

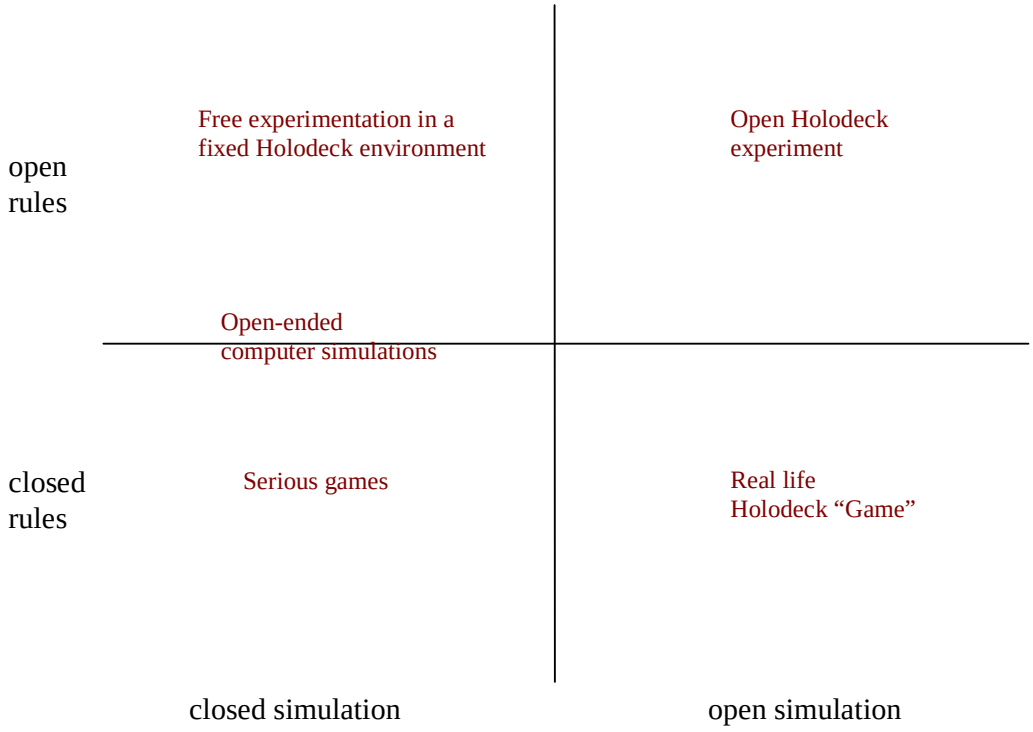

Figure 6.1 – Open and closed simulation and rules.

Open rules, on the other hand, give participants the freedom to experiment without limitations; they may find new uses for tools, compose more effective or more efficient processes and discover creative solutions.
As can be seen in Figure 6.1, open-ended computer simulations are placed between open rules and closed rules. The reason for this is that, although players are left free to choose their actions and organize their process in any way they like in an open-ended computer simulation, this experimentation will always be limited by the kind of parameters that can be changed. Although the actions players may perform have been predefined at an elementary level, they may still be used and combined in ways that are creative and were not predicted.

6.1.2 Physical situatedness

The use of a Holodeck environment itself as a part of the simulation may have other implications besides creating "openness". Looking at game elements, it may be found that this way of using a Holodeck has important implications for the situatedness of a serious game. While in regular serious games, players are only mentally present in a game environment, participants in a Holodeck will become physically present in the simulated world as well. This means that certain aspects of their physical behavior may suddenly become of importance to the game, leading back to the discussion of openness.

Furthermore, while in regular video games the mental presence of the players is often accomplished by means of an avatar (a virtual character the players can control), in a Holodeck environment the players may become the main character of the story themselves, both mentally and physically. This way, a Holodeck simulation may turn into a kind of real life role-playing. There are also a number of video games that do not use avatars, such as simple puzzle games, strategy games and simulation games like Sim City and Roller Coaster Tycoon. Whether there is a possibility to create a specific role which might be played in a Holodeck simulation and whether such a translation is useful will have to be considered carefully in each specific case.
Nevertheless, physical situatedness may provide a number of advantages to a serious game. Although the hypothesis would have to be tested, it seems likely that physical situatedness will enhance the sense of realism and by its total submersion improve engagement and thereby attractiveness.
A drawback of physical situatedness is that some of the negative effects that might occur during a simulation will also be real, such as physical harm, or damage to equipment or the game world. In such cases virtual simulation may be a better option.

6.1.3 New forms of interaction

The use of a Holodeck may cause changes in the way in which interaction takes place within a serious game. First of all, a Holodeck may provide alternative devices for input and output. Instead of providing standard devices such as a mouse and keyboard and a single monitor, a wide variety of other devices may be offered as well, depending on the situation for which the Holodeck is used. The easiest example of this is that of a flight simulator. In this environment, a pilot is presented with all instruments one would normally find in a cockpit. Simulation of movement may be an additional form of feedback that is provided in such a simulator. Other examples of non-standard interaction devices may be found in the field of virtual reality, such as special helmets or glasses that can visualize virtual environments, or gloves with “force feedback” that can simulate physical forces and touchable objects.
When a Holodeck is used as a part of the game world, there may also be a number of changes in the way in which human interaction takes place. Communication and collaboration between participants may occur face-to-face, providing easier and richer communication than for instance chat facilities. Participants may also collaborate by actually performing a task for another person, rather than just explaining how to do it. Whether such collaboration needs to be restricted in for instance a training environment should always be considered carefully.
Next to communication between participants, the use of a real world game environment may also change the way in which participants interact with other characters in a simulation. A game master may act in various roles, such as a customer or a victim of an accident, creating a form of real life role playing. Such interaction may be much richer and much more realistic than having an artificial conversation with a NPC (non-player character) in a video game. Such communication is also open to improvisations and may therefore contribute to a more open simulation. A Holodeck may also contain phones or other communication devices that allow for communication in a way that is appropriate for the reality that is being simulated.
Alternative input and output devices, human interaction and appropriate mediums for communication may increase the realism of a simulation. They may also allow for the simulation of realities that are difficult to simulate in a virtual way and allow for more open interaction.

A disadvantage of any interaction that does not involve the use of a computer is that the computer system doesn't have any way of monitoring and controlling such interaction either. This means that the enforcement of rules and the monitoring of a score system cannot be done solely by an information system and will have to be done in some other way.

6.1.4 Support of reflective learning

A Holodeck that has been set up in the way that was discussed in section 5.3 provides a number of tools and methods that have been identified as being able to support a reflective learning strategy.
First of all, a Holodeck makes it easier to let participants cooperate and collaborate during an experience, since a group of participants is already brought together in a single environment during a Holodeck session. Besides this, the concept also assumes that a number of experts are present during the session, who may offer guidance to the participants and the whiteboard and flip-over can be used for debriefing and group discussions. In fact, the Holodeck already incorporates this method of supporting reflective learning as a separate phase of a Holodeck session.
Support of reflective learning is an advantage that may be provided both by a Holodeck that is used as a simulation environment itself and a Holodeck that offers the tools for a virtual simulation.

6.1.5 Environment for surrounding training program

If a Holodeck is used for training or educational purposes, the setup discussed in section 5.3 may provide an environment that can be used for other parts of a training or educational program as well. There are tools for presentations, discussions and the four phases of a Holodeck session provide a clear structure for training and education.

6.2 Added value of serious gaming for a Holodeck

The use of serious gaming as a learning or communication tool has been advocated by many writers. Abt [1], for instance, wrote, "*Games are effective teaching and training devices for students of all ages and in many situations because they are highly motivating, and because they communicate very efficiently the concepts and facts of many subjects.*"
But what added value can serious gaming provide in a Holodeck setting? To discover this, the concepts of a Holodeck and a serious game will be compared in this section.

When looking at the question what serious gaming has to offer in a Holodeck setting, a distinction can be made between the use of game technology, such as 3D visualizations, and the use of game elements, such as story and competition. Two ways of using game technology may be distinguished:

- Game technology may provide a virtual simulation: a game world and an underlying model.
- Game technology may be used to manage issues related to gameplay: enforcing game rules, providing a storyline/sequence of challenges and keeping track of scores.

Whether game technology should be used in either of these ways depends on the purpose for which the Holodeck is used, the openness that is desired and the kind of reality that is being simulated. Rich 3D visualizations such as the ones that are used at T-Xchange [39] can be highly suited for creating virtual worlds and for the design of physical products, but may be less useful when dealing with a large administrative system.
Similarly, the possibilities for the use of game elements in a Holodeck setting will also depend on the purposes for which it is being used and the way in which it is used. If open experimentation is desired, a Holodeck environment has no use for a fixed storyline or a solid set of rules. Likewise, such elements may be difficult to introduce into a dynamic Holodeck environment, of which the form is constantly changing. Because of this, it may not always be possible to create a full serious game containing all six of the elements discussed in section 2.2.1, but game elements may also be introduced separately into a Holodeck experience. What benefits these elements and the use of game technology may offer will now be examined. Note that game elements may also be used without the support of IT.

6.2.1 Added value provided by the use of game technology

Interactive simulations
An important aspect of computer simulations is that they can be designed to be highly dynamic, meaning the simulation can adapt to the input provided by the player. With a proper underlying model, computer simulations can be used to let participants experiment and play with different situations in a simulation, immediately receiving feedback about the consequences in an explicit form.

Visualization
Game technology may be used as a tool for visualization. Detailed virtual representations eliminate the need for users to create their own mental images and can make it easier to spot

problems and opportunities. It will also ensure that people share the same mental images and definitions of concepts.
Game technology can be used to demonstrate the behavior of dynamic computer simulations, visualizing the consequences of the changes participants make to the simulated world. Proper visualizations may also increase the realism, completeness and attractiveness of a Holodeck simulation and hence the engagement in the fantasy that is created.

Virtual simulations allow for the simulation of environments or objects that are difficult or expensive to create in a real world environment and the experimentation within such an environment may be quicker and less expensive as well, without any risk of damage in the real world.

6.2.2 Added value provided by the use of game elements

Game elements may be added to the setup of a Holodeck environment and a Holodeck session to enhance the Holodeck experience in various ways, depending on the situation in which they are used. These possibilities for providing added value will now be discussed. Note that game elements may be introduced in both a digital and a non-digital way in a Holodeck.

Attractiveness
Games have a number of characteristics that make them attractive. Visualization of an alternative reality by means of digital representations and the introduction of a story may prickle fantasy and curiosity, while goals, competition and uncertainty may cause challenge, stimulating the players' will to perform.
While interaction, an underlying model and some form of situatedness should already be a part of any Holodeck experience, these elements that add to the attractiveness of games may not be useable in every Holodeck environment. Free experimentation (the use of open rules) during a Holodeck session prohibits the use of a fixed storyline, while the dynamic use of a Holodeck would require the development of a new storyline for each session. Similarly, if the design or optimization of a solution to a certain problem is the purpose for which a Holodeck is used, this is a challenge in itself and putting additional goals and obstacles in front of the player is likely only to distract them. If a Holodeck is used to familiarize participants with a static "reality" however, providing an interesting goal which the players may strive to achieve may be a good idea. Similarly, competition may be undesirable in situations in which collaborative design is the goal of a Holodeck session. On the other hand, an optimalization process may become more attractive if a scoring mechanism is developed by which performance can be compared with that of previous sessions. Whether such performance metrics can be developed in a specific situation is another question however.
If competition or additional challenges are introduced into an environment that is intended to be open, one should be careful not to impose rules related to such challenges or forms of competition that limit the players' creativity.
In general, it seems these elements that may improve the attractiveness of a Holodeck experience are particularly suited to be used in static and "closed" environments, in which an experience may be created in which all game elements are included. Depending on the situation, certain game elements may be added to a Holodeck that is used in a dynamic way as well however, or aspects of the experience such as goals and challenges may be presented in a

game-like fashion. If the attractiveness of a Holodeck experience can be improved in one of these ways, it is likely to enhance the active participation of participants.

Guidance and story

Besides helping to create a fantasy which players might engage in, the element story may also be used to provide a certain guidance and structure to a Holodeck session.

Facilitators may want participants to experience a number of different aspects of a simulated reality during a Holodeck session. A story can deal with all of these aspects by creating a series of events and can link these events in a logical, possibly engaging way. This way, the story guides the players through all the important issues of a reality.

The story may guide them through each individual task as well, offering a step-by-step walkthrough for the players. Besides this, it may be used to present the players with the appropriate context for each task and it can also help to exemplify concepts and situations, aiding in the goal of making them explicit. Game technology can bring stories to life with a combination of text, audio and video, all in an interactive way.

6.3 Usability of assessment methods for serious gaming for a Holodeck

In Chapter 3 of this text a number of methods and tools that can be used to determine the effectiveness of a serious game as a teaching tool have been discussed. In this section, these tools and methods will be revisited and their usability in a Holodeck setting will be described. Note that a number of these tools and methods focus on assessing what a person has learned and may therefore primarily be used within a Holodeck environment that is meant to teach something, such as a Holodeck that is used for training. Some methods and tools, such as the tracking of players' actions, corrections and performance and interviews and observations may also be used for other purposes such as process improvement, to determine the effectiveness of a Holodeck in these situations.

6.3.1 Traditional methods for assessment

In section 3.1 a number of traditional methods for assessment that can be used in the assessment of serious games have been discussed. These methods may be applied to a Holodeck setting as well.
Traditional methods, such as limited-choice questions and interviews can be used before, during, or after (a certain part of) a Holodeck session to measure the effectiveness of the (part of the) Holodeck experience as a teaching tool. Such methods can be used to measure not only the effectiveness of a serious game that is played within a Holodeck, but the effect of presentations given as an introduction and the insights gained during group discussions and reflection as well.
The reflection phase of a Holodeck experience, described in section 5.3.1, may also be used as a moment for assessment in itself. Through group discussions and interview questions, facilitators may get an impression of what participants learned during a Holodeck experience and what still needs to be clarified.
Observation is a method that may be used in a Holodeck as well and may cover both interaction within a digital game environment and interaction not concerned with the use of a computer. Observation of players becomes easier in a Holodeck environment since there will already be one or more facilitators and experts present. If physical presence of these observers within the Holodeck environment is undesirable during a Holodeck experience, such observation may occur by means of cameras or something like a one way mirror, next to any digital monitoring of the players' behavior within a game.

6.3.2 Assessment challenges

Some of the challenges faced in the assessment of serious games with traditional methods, which were discussed in section 3.2.1, seem to hold for the assessment in a Holodeck setting as well and maybe even to a larger extend. The difficulty of assessing the different results that may be reached in an open-ended simulation will only increase as a Holodeck offers a wider range of possibilities for interaction to a serious game, as was discussed in section 6.1.1. At the same time, measuring the improvements in abstract skills such as teamwork, for which a Holodeck may be a suitable learning environment, will still be an issue that needs to be dealt with.

6.3.3 Useful features of entertainment games for assessment

In section 3.2.2 a number of features of video games that may already include some form of assessment have been discussed: *game levels*, *tutorials*, *scoring* and *assessment through game construction*. Most of these can be applied to a Holodeck experience as well.
A game level mechanism basically comes down to letting players perform a series of tasks before they are provided with a new, more advanced set of challenges. As such, a game level mechanism may also be applied to any (part of a) Holodeck experience that takes place outside of a computer program. Similarly, a scoring mechanism can also be set up for any interaction that is not concerned with computers. The only new challenge is keeping track of such scores and combining them with any scores that are measured within the video game.
Assessment through game construction seems to be applicable in the same way as was discussed in section 3.2.2. Tutorials however, are harder to convert to the real world. Although the sequence of instruction followed by practice can be translated to actions outside of a computer system, such as a step-by-step instruction on how to put together your own computer in the form of a manual, the third step of assessing whether a certain action was actually performed (and performed in the right way) is more difficult to include. Assessment by facilitators is a possibility of course, but this will be laborious and may disrupt the flow of a game.

6.3.4 Serious game specific methods for assessment

In section 3.2.3, three serious game specific methods for assessment have been discussed. The addition of a Holodeck to serious gaming may have a number of consequences for the use of these methods.
Completion assessment can be used in much the same way as it can be used for video games. If a task is set up properly, completing it will be some proof of a player having mastered the material regardless of the environment in which this task is completed.
In serious games, tracking of the players' actions and corrections that are used to reach a certain result can be done automatically to facilitate in-process assessment. In a Holodeck experience however, actions outside of the computer system that are relevant for the learning experience will have to be tracked (and recorded) in some other way. The most obvious way to do this is through observation. Videotaping might be used as a tool in this process, but one should note that, if one wants to follow the game directly with a moment of reflection and group discussion, it will be wise to make a direct observation of the players' actions as well. Of course, any behavior that was recorded either on video or in the video game may be used as a support for such discussions.
Just like with serious games, teacher evaluation is a useful assessment method for a Holodeck as well, even more so because there may be more abstract actions that need to be taken into account, such as the occurrence of teamwork. Nevertheless, the statement of Michael and Chen [23] that was quoted in section 3.2.3 that the more data is available, the less subjective that evaluation needs to be, still holds.

7. Case study – the use of the Holodeck concept at the Belastingdienst

The concept of a Holodeck that has been developed at GPR has been applied for the first time during the development process of a new system for the processing of "toeslagen" at the Belastingdienst. In fact, there have been two kinds of Holodecks at the Belastingdienst, each designed for a different purpose.
The first Holodeck is the one that was described earlier in section 4.1 and used the setup of the environment and session that was described in section 5.3. This Holodeck was used during so-called PoCs (Proof of Concepts) that were held a number of times during the development process of the information system for Toeslagen.
The second kind of a Holodeck that was developed at the Belastingdienst was an entirely different kind of Holodeck. It was intended to deal with the subject of change and collaboration that is required to make these changes successful on an emotional level. It offered participants an experience that consisted of watching a number of videos and video fragments and performing tasks as a group within the Holodeck environment in order for the experience to progress. It was intended to be used before the rollout of the new information system in the organization, but for reasons that will be described later on this has not been the case. This second Holodeck was created by students of the School of the Arts in Utrecht (HKU or "Hogeschool voor de Kunsten Utrecht" in Dutch) and shall be referred to as the HKU Holodeck to separate it from the Holodeck that was used during PoCs, which shall be referred to as the PoC Holodeck after this.
This chapter will provide a case study of how a Holodeck might be used, dealing with both of the Holodecks at the Belastingdienst. In section 7.1 the PoC Holodeck will be discussed, giving a description of its purposes, its setup and looking back at its successfulness. In section 7.2, the HKU Holodeck will be discussed in much the same way, explaining its setup and purposes and then looking at the reasons for which the environment was not used as it was intended and the ways in which it was successful regardless of this. This will be followed by an identification of the lessons that can be learned from this.

7.1 The PoC Holodeck

The PoC Holodeck and the PoC sessions that were held here were used to present a new information system in its various stages of development to a specially selected group of end-users. The system would process as much of the notifications concerning "toeslagen" automatically. If automatic processing was not possible, the system would present a notification to these end-users, to be processed manually, which would also be supported by the system.
During the PoCs, these end-users were introduced to the parts of the system that had been completed so far. There have been three PoCs for which the PoC Holodeck was used. What purposes these PoCs served and how these PoCs and the Holodeck were used will now be discussed.

7.1.1 Purposes of the PoC Holodeck

The PoCs at the Belastingdienst had a number of goals, for which the Holodeck was used as a tool. These goals are listed below, stated in terms of the purposes described in section 5.1.

- *Serving as a design instrument*, in a limited way: The overall design was predefined, but feedback during the PoCs would still be useable for making small-scale adjustments and identifying future requirements.
- *Supporting sales*: Although there already was a contract with the Belastingdienst one of the purposes of the PoCs was to demonstrate that the development was going in the right direction.
- *Optimizing processes*, in a limited way: Experimentation with the new system could lead to new insights about the implications on the surrounding process.
- *Assigning value*, in a limited way: The "toeslagen" system was delivered in several components. Experimentation with the functionality completed components offered could be used to give a global estimation of their value (in a non-monetary way).
- *Serving as a training instrument*: The PoC Holodeck was intended to be used for training as well, although it is unknown whether this actually happened at this point of writing.
- *Supporting change management*: This was one of the main purposes of the Holodeck. It was intended to present the new system in an interesting way, create a feeling of involvement in the development process among end-users and illustrate what the new system and process would look like and what implications their introduction would have on these end-users.

7.1.2 Description of the PoC Holodeck

The Holodeck environment was set up at the office of the Belastingdienst and followed the format that was described in section 5.3 and illustrated in Figure 5.2. The Holodeck session also followed the format of the four phases described in section 5.3 and the content of these phases during the PoC sessions will now be described.

1. Introduction
During the introduction phase, a beamer was used to support presentations. These presentations usually included the following information:

- An explanation of the general way in which notifications are processed by the new information system and process.
- A timeline of planned system development and milestones (planning of completed functionalities).
- A small reflection on what was done during the previous PoC.
- An explanation of the content of this PoC and the PoCs after that.

2. Experience
For the experience phase, four standard PCs had been placed on a desk along one side of the room, simulating possible work stations of end-users. During this phase, participants were

provided with a partial version of the “toeslagen” system. During each PoC, new functionalities that had been developed since the last session were available to be used.
For each session, a number of tasks were added to the workload in the system. That is, a number of dummy notifications were supplied that each contained a different error that required participants to deal with another part of the information system. During the session, participants were given a paper manual that provided an explanation of the interface of the system, the kinds of errors occurring in the tasks they needed to perform and the overall flow of a task through the system before and after manual processing. The manual provided a step-by-step walkthrough to guide them through a series of tasks as well.
Participants worked in pairs and were free to ask questions of the experts that were present during this experience phase.

3. Reflection and abstraction
After having worked with the “toeslagen” system, participants were involved in a series of group discussions. These discussions were guided by a facilitator and supported by the use of a whiteboard and flip-over. The whiteboard was used to provide visual support to discussions and explanations, while the flip-over was used to capture findings in a more definite way so they could be documented. The discussion was focused on the following topics:

- Winding up the discussion about any small bugs that slipped through the testing department and were reported during the previous phase.
- Placing the tasks performed in the experience phase in the overall process to continue the discussion at a higher level.
- Identifying which parts of the current solution are good, which need to be improved an which are still missing.

4. Implications

During the implications phase, the implications of the experiences with the system for the Belastingdienst, the Toeslagen department and the work in this department were considered. The progress of the development process was compared to that of the overall planning and the planned date and content of the next PoC.
A number of images, graphs and models were hung on one wall of the Holodeck to support this discussion, these were:

- An image in which the four most important stakeholders were represented: citizens, the management board of the Belastingdienst, the “Toeslagen” department and national politics.
- A process model illustrating the different notifications that can be received by the “toeslagen” system and the way each of them should be processed.
- A graph illustrating the planned development process and the moments at which PoCs would be held.

7.1.3 Evaluation of the PoC Holodeck

Looking back at the use of a Holodeck at the Belastingdienst during PoCs, it can be concluded that its use has been fairly successful. Participants responded well during and after the Holodeck sessions and it has been able to support the goals for which it was set up.
It can be noted that the Holodeck was not used in the exact way that was described in section 5.2. Ideally, the Holodeck should be used in situations in which the form of a solution to a problem is still unclear. In this case, the development of the "toeslagen" system followed a traditional design approach and the specifications and design of the application were determined before the Holodeck was used for the first time. As such, the Holodeck could not be used as a tool to generate a new "reality" and transfer this back to the actual reality. The Holodeck was able to support the design process by identifying issues that could be solved with small scale adjustments.
Besides this limited role in the design of a new reality, the Holodeck sessions focused on discovering the implications this new reality (the new information system and surrounding process) would have and on determining whether it actually offered a "workable" solution and whether there was enough support for this new solution. In this, the use of a Holodeck can be considered successful, according to De Haas.

7.2 The HKU Holodeck

The other Holodeck that was developed at the Belastingdienst was an entirely different one than the PoC Holodeck. Leaving the office environment behind, an interactive experience consisting of video fragments and tasks that needed to be performed in an interactive environment was developed. This experience and the Holodeck environment were created by a group of AVM (Audio Visual Media) students and a group of DMD (Digital Media Design) students of the HKU. The purposes for which they developed this Holodeck and the shape this Holodeck took in the end will now be discussed.

7.2.1 Purposes of the HKU Holodeck

The HKU Holodeck was primarily created to deal with issues of change on an emotional level, which would be caused by or required for the introduction of the new "toeslagen" system and surrounding work process. Like the goals of the PoC Holodeck, these may also be stated in terms of the purposes described in section 5.1.

- *Serving as a training instrument*: The HKU Holodeck was intended to be used as a part of the training program, but in the form of "mental preparation" rather than actual training.
- *Supporting change management*: The new information system and process would lead to a new way of working and required a new attitude on a number of points. The HKU Holodeck was intended to deal with a number of changes at an abstract level: collaboration, trust (in each other and toward citizens) and a change toward a work process that is driven by the events in the lives of citizens, rather than formal procedures and rules at the Belastingdienst.

While the PoC Holodeck was intended to let participants experience and experiment with a certain (simulated) reality, the HKU Holodeck was aimed at changing the perception of a reality. It was intended to affect both the attitude participants had towards the new information system and work process and their attitude toward change.
Altering the "*perception*" or "*attitude*" of participants may be very important in certain situations. It can be necessary to force participants out of their old thinking patterns before the creation of a new solution, or the way participants look at a (future) "reality" may need to be changed before they are able to understand and appreciate a new way of working.
This way, a Holodeck focused on changing the perception of a certain reality may become what might be called a "tool" that can be used for reaching other purposes (of other Holodeck experiences). Nevertheless, since change of perception was the only purpose of the HKU Holodeck, it should also be seen as a separate, "serious" goal which a Holodeck might serve.

The way in which the HKU students tried to alter the perception of Holodeck participants will be discussed next.

7.2.2 Description of the HKU Holodeck

During interviews the employees of the Belastingdienst indicated that the way in which they experienced their current work situation could be compared to that of a mole; being in the dark and only occasionally catching glimpses of the outside world through a small hole. For this reason, the HKU students decided to locate the Holodeck experience in an underground setting, a room resembling an underground power plant, to be more precise.
Participants enter this environment without knowing exactly what to expect. At this point, the room is still very dark. After pushing a big red button, a sequence of video fragments starts playing on a monitor hanging on one of the walls, guiding the participants through the experience. The first video shows a machine processing paper notifications for “toeslagen”, and then a number of other machines, breaking down in a chaotic compilation of images. More lights in the environment go out and red emergency lighting is turned on. The monitor now displays a “news item” that informs of an energy crisis in the Netherlands. As the story progresses, participants learn that the environment they find themselves in is in fact a power plant that needs to be brought back into operation and that they are the ones who have to do this. They are supported in their task by “someone” speaking from a higher level of the power plant: in a “shaft” in the ceiling, a monitor displays a person who asks the participants to perform a number of tasks, such as reconnecting wires and replacing batteries. These tasks require cooperation and are often presented as a kind of puzzle or challenge. As participants complete these tasks, new “news items” will be shown. Fragmented through all this, there is also another video that is displayed, which tells the story of “Felix Fiscalini”. Due to his bad handwriting, some of the information on his “toeslagen” notification form is processed incorrectly and these errors are reflected in his actual life: he grows old because his date of birth has been entered incorrectly and because a “0” was mistaken for a “6” in one of the fields he is suddenly surrounded by a bunch of children. In the end, Felix sends in a new notification via the online portal and his life is restored back to normal, while the energy crisis also comes to an end around the same time. The experience ends with a news item in which it is announced that a new system for “toeslagen” will be developed because of certain unfortunate events caused by incorrect processing in the old system.

7.2.3 Similarities with serious gaming – the presence of game elements in the HKU Holodeck

Although the experience provided by the HKU Holodeck was not often referred to as a “serious game” or just a “game”, it shows a number of obvious similarities with games. In fact, all game elements that have been discussed in section 2.2.1 may be found in the experience.

There is a clear goal for the participants during the experience, although this is not known at the start: they have to resolve the energy crisis in the Netherlands by bringing the underground power plant they find themselves in back into operation. To do this, they have to overcome a number of challenges as a group, such as forming a human chain between two points in the environment to redirect an electrical current. There are also rules that determine when such tasks have been completed successfully.
Interaction is obviously present as well: as soon as the participants have completed a task, such as creating the human chain, the story will continue and the group will be complimented

on their work by the “person” at the top of the “shaft”. The environment will also grow brighter each time a task is completed by lights that are switched on.
There is also room for uncertainty within the experience: participants are provided with some advice that gives a hint of how to complete each task, but some of these hints remain vague and participants will have to look around and experiment in the environment to discover how to complete them.
There is no competition between participants or competition in the form of beating a high score, but participants are faced with the challenge of beating the system together.
Finally, the experience is clearly situated in a specific “fantasy”: The game world consists of both the physical environment the players find themselves in (the power plant) and the world that is presented to the player through the videos that are displayed. Furthermore, the experience tells a story through the different videos that are displayed. In fact, there were two stories: the story of the power plant and the energy crisis, in which the participants played an active part, and the story of Felix Fiscalini, which was actually somewhat separate from the rest of the experience, but was shown in fragments between the other videos.

The HKU Holodeck shows how a real-world environment may be used as a game environment. It also demonstrates that it is possible to set up a Holodeck experience in such a real-world game environment, while still being able to let this experience be controlled by a computer program.

7.2.4 Why has the HKU Holodeck never been used?

When the HKU Holodeck had been completed, it was demonstrated to the group of end-users that had been selected for the PoCs. They showed a positive response to the experience and indicated that about 80% of their colleagues would be interested in visiting the Holodeck as well. The Holodeck was also shown to the Management Team (MT) of the Belastingdienst and they showed a considerably less enthusiastic reaction. There had been one member of the PoC group who did not feel comfortable in the Holodeck environment and had left the room at an early stage and the MT made an issue of this. They indicated that the environment was too dark and gloomy. Furthermore, they indicated that the experience lasted too long, while the available time for training was very short and in the end they decided that the HKU Holodeck would not be used in the training program and should be dismantled.
This decision is in contradiction with the enthusiasm of the group of end-users. One of the explanations that have been suggested for this is that many end-users belonged to the game generation, while the MT consisted mainly of people belonging to the non-game generation. This may explain why the PoC group was able to appreciate the game-like environment, while the MT was not.
According to one of the people who supervised the development of the Holodeck at the Belastingdienst, the contradiction may have another explanation, that doesn’t lie with the Holodeck experience itself: the initial concept for the Holodeck was approved by the MT, but this was done by a member who left the organization shortly after that. After this, no replacement could be found within the MT to take over the task of supervising and monitoring the development of the Holodeck up-close. Due to this, once the Holodeck had been completed, the MT was surprised by the looks of the Holodeck and the goals it tried to achieve. Subsequently, they did not try to consider the experience from an end-user point of view, but stuck to their own, not allowing themselves to be engaged in the experience.

This explanation indicates that the rejection of the Holodeck may have been due to a failure to involve all relevant stakeholders and decision makers, rather than a failure to create the right experience. Because the Holodeck was dismantled shortly after the decision of the MT, this is a question that could not be researched any further.

It should also be noted that the HKU Holodeck was not entirely discarded by the MT. The Holodeck will be rebuilt at another location, to be displayed at the Future Center of the Belastingdienst. MT also indicated that they were still interested in the video material that was made for the Holodeck experience and would use this in the training program separately.

7.2.5 Lessons learned

Regardless of what the most important reason for the rejection of the HKU Holodeck as a training tool was, there are a number of lessons that can be learned from it.

- The physical submersion of participants in an environment may have a stronger impact on people than a game world displayed on a screen. If an environment or experience could be conceived as threatening, such total submersion may become too much to handle for certain people.
- Active involvement of all important stakeholders and decision makers before and during the development of a Holodeck experience is required. Stakeholders should be aware of the purposes for which a Holodeck will be used and of the way in which the developers intend to reach them. A clear concept should be set up and approved in advance and the resulting environment and experience should be demonstrated a number of times during development, to create concrete and realistic expectations.
- There may be people who cannot, or do not want to understand the usefulness of unconventional teaching methods such as games or of “abstract” goals such as the ones of the HKU Holodeck. If their objections are unfounded, one may try to convince such people, remove them from any crucial decision making positions, or, if this is not possible, try to concede to them by including purposes they can understand. Assessment may be used to provide the evidence that a Holodeck experience is effective in reaching its purposes.

8. Conclusions and recommendations

In this section, an answer to the research question of this thesis shall be given and recommendations for future research and for GPR shall be provided. Before this, an answer to each of the individual sub-questions stated at the beginning of this text shall be given.

8.1 Answers to sub-questions

Which design techniques and game elements can be used for the development of effective serious games?

Serious games can be effective tools because of their attractiveness. This attractiveness is caused by *fantasy*, *challenge*, *curiosity*, and *engagement* caused by *flow*. Such attractive characterisics may be integrated into a game by making use of game elements: *a challenging goal, rules and an underlying model*, *competition*, *interaction*, *uncertanty* and *situatedness and story*. The way in which these game elements are given shape in a serious game should depend on the purposes for which it is used and on the personal characterisics of its intended players.
Games are organized in a way that encourages its players to use an *experiential learning strategy*. In serious games, it may be necessary to stimulate the use of a *reflective learning strategy* as well, which may lead to new explicit insights and strategies which can be transferred to other contexts. Based on research of Leemkuil [19], a number of tools and techniques have been identified that may stimulate the use of such a reflective learning strategy, which are: *feedback, guidance, additional assignments, cooperaton and collaboration, debriefing and group discussions* and *monitoring facilities*. Stimulating the use of both an experiential and a reflective learning strategy can increase the effectiveness of a serious game.

What are possible ways for measuring the effectiveness of serious games?

Serious games may draw on assessment methods used in traditional learning environments and e-learning (tests, surveys, interviews and observation), but serious games can provide a number of challenges that may make these methods less useful: there may be *less emphasis on the rote memorization of facts*, *assessment in open-ended simulations* can be difficult, as well as the *assessment of abstract skills* and the way in which one should deal with *cheating*.
As Michael and Chen [23] point out however, many video games may also already provide some way of assessment in the form of *game levels*, *tutorials* and *scoring*. Based on their research, three serious game specific methods of assessment have been identified as well: *comletion assessment*, *in-process assessment* and *teacher evaluation*. These should be able to deal with the challenges faced in the assessment of serious games.

What is a Holodeck and what purposes may it serve?

A Holodeck has been defined as: "*an environment in which realities of a complex nature can be simulated and a group of people can interact and experiment with or within this*

simulation, with the primary purpose of finding a solution of an unknown nature to a complex problem".
A Holodeck is intended to provide an experience to a group of participants. It lets them experience a certain "reality" (situation, process, environment, etcetera) and interact within this reality. To make such an experience as rich as possible, a Holodeck seeks to submerge its participants fully in this experience, mentally, emotionally and physically. It seeks to create a simulation that is as realistic, detailed, open and engaging as possible. Such an experience can then be used to understand, analyze and possibly change and improve this "reality".
A Holodeck environment may either contain the tools to provide a virtual simulation, or the environment may be used as a part of the game world itself. It may be used for several purposes, of which the following were identified in an interview with De Haas:

- Making the use of applications transparent
- Supporting strategical decision making
- Serving as a design instrument
- Supporting sales
- Supporting requirements definition
- Optimizing processes
- Assigning value
- Creating a business case
- Serving as a training instrument
- Supporting change management

A format has been introduced for the setup of both a Holodeck environment and a Holodeck experience, which consists of four phases: An *introduction phase* in which the purposes of a Holodeck session and required background information can be presented, an *experience phase* in which participants can interact with(in) a certain simulation, a *reflection and abstraction phase* in which participants reflect on their experiences and translate them to an abstract level and an *implications phase* in which they can determine the implications of their experiences for the organization and the development process.

What are the possibilities for combining serious gaming with a Holodeck environment and which advantages may this provide?

The concepts of serious gaming and a Holodeck show a number of similarities and may be able to provide added value to each other in a number of ways. The possibilities for providing such added value depend on a number of factors: the purpose for which a Holodeck or serious game is used, the content of the simulation and the way in which a Holodeck is used. A Holodeck may be used to provide a virtual game world or may be used as a real-life game world. Besides this, a distinction can be made between the dynamic use of a Holodeck and the static use of a Holodeck: a Holodeck in which the "reality" is constantly changed and improved based on the experiences during a previous session and a Holodeck which offers a fixed reality to its participants, such as a training environment.

If a Holodeck is used as a real-life game environment it may provide several advantages to a serious game. Where serious gaming offers an experience of which the *openness* is limited because both *simulation* (the game world and its behavior) and *rules* (rules determining the ways in which participants may interact with(in) a simulation) have been abstracted and determined in advance, a real-life environment is open for unexpected events and behavior.

As a result, a real-life game environment may be best suited for a Holodeck that is intended to be used in a dynamic way and in which free experimentation is allowed. On the other hand, an abstracted simulation may be more useful in a learning environment and closed rules may provide structure in a static Holodeck, but may be useful in a dynamic Holodeck in some cases as well.
Other advantages of a real-world game environment are its possibility to increase *engagement* through *physical situatedness* and its possibility to enhance realism by means of alternative devices for input and output and human interaction.
The format for a Holodeck environment and a Holodeck session that was presented in this text (*introduction, experience, reflection and abstraction* and *implications*) may support the use of a reflective learning strategy. The setup provides an environment in which participants can cooperate and in which guidance can be provided by experts, while debriefing and group discussions may be addressed in the reflection and abstraction phase. Besides this, the setup of a Holodeck session may also be used as a structure for an entire training program surrounding the use of a serious game.

Serious gaming, on the other hand, may also be able to provide added value to a Holodeck. This may be achieved by the use of both game technology and game elements.
Game technology may provide computer simulations that are highly dynamic, capable of adapting quickly to the input provided by the players, which lets them experiment with different situations in a time and cost effective way.
Game technology may also serve as a tool for visualization, providing a detailed virtual representation which can make abstract concepts explicit and can ensure that all participants share the same mental image. Proper visualizations may also increase the realism and attractiveness of a Holodeck simulation, but whether rich visualizations such as 3D environments are useful always depends on the content of a simulation.
Game elements may be used as a tool for making a Holodeck experience more attractive, by adding a story, goals, competition and uncertainty. A story may also be used to provide a certain form of guidance: it can ensure that players are introduced to all relevant aspects of an experience, provide illustrative examples and provide the necessary context and step-by-step guidance for the tasks that players need to perform.
Such a fixed storyline can only be created for a Holodeck that is used in a static way. In general, it seems that a static Holodeck is the only form in which a full game may be set up, although individual game elements may also be useful in a Holodeck that is used in a dynamic way.

Does a Holodeck require or facilitate alternative ways of measuring effectiveness?

A Holodeck may use the same methods for measuring effectiveness as serious games, including traditional assessment methods, characteristics of games that may be used as a tool for assessment (*game levels*, *tutorials* and *scoring*) and serious game specific methods. Most of these methods focus on measuring whether players learned anything during an experience and are therefore best suited for a Holodeck that is used as a learning environment. Besides this, the use of game levels, tutorials and scoring may become more difficult in a Holodeck because not all interaction can be monitored and controlled by a computer system. This means any interaction that takes place outside the scope of a computer system will have to be monitored and processed manually and where necessary should be able to be integrated with parts that are controlled by a computer system. At the same time, a Holodeck environment and Holodeck experience may support group discussions and interviews, which can be used

for assessment as well. Assessment in a Holodeck may also be used to measure the effectiveness of the *introduction phase* and the *reflection and abstraction phase*.

8.2 General conclusion

Which design techniques can be used for the development of effective serious games, how can this effectiveness be determined and how can serious gaming and a Holodeck environment support each other?

This was the main research question of this thesis. Based on the discussion above, it may now be concluded that game elements can be used as a way to design a serious game and ensure its attractiveness. They can also be used as a basis for considering the way in which serious gaming may be used in a Holodeck to provide structure and guidance and increase attractiveness. At the same time, game technology may be used to provide interactive simulations and visualizations that may be used in a Holodeck.
Based on research of Leemkuil [19], a number of tools and methods that could increase the use of a reflective learning strategy in serious games were identified and further research indicated that a number of these methods are supported by the setup of a Holodeck. A Holodeck may further provide advantages to serious gaming in the form of openness, physical situatedness, alternative forms of interaction and by serving as an environment that can be used for an overall training program which surrounds the use of serious gaming.
Many of these advantages are case specific and the extent to which serious gaming and a Holodeck may support each other may vary. Factors that can be of influence are: the purpose for which a Holodeck or serious game is used, the content of the simulation and the distinction between the dynamic and static use of a Holodeck and the use of a Holodeck as an environment that provides a virtual game world or an environment that serves as a real-life game world.
The effectiveness of serious games can be measured by means of assessment methods found in traditional learning environments as well as by methods found in entertainment games and serious game specific methods for assessment. Many of these methods can also be used for measuring the effectiveness of a Holodeck environment, but since most of these methods assess whether participants learned anything they may be less useful in a Holodeck that is not used as a learning environment.

8.3 Future research

In this research on serious gaming and the Holodeck concept a number of issues have been discussed that may be interesting topics for future research. A number of suggestions can be found below:

- In this research a number of serious game specific methods of assessment and element of entertainment games that may already provide some form of assessment have been discussed. It may be useful to explore how such methods may be used for a formal assessment in more detail.
- The assessment methods discussed in this research focus primarily on measuring whether people learned anything. A Holodeck may be used for a number of other purposes besides training and education however and therefore it may be useful to explore ways of determining the effectiveness of a Holodeck in reaching these other goals as well.
- The use of a Holodeck as a real-life game environment and physical situatedness are topics that go beyond the scope of Information Sciences and their implications may be studied from other perspectives, such as the field of psychology, as well.
- Although the combination of serious gaming and the Holodeck seems to be a beneficial one, both concepts may take on many different forms and serve many different purposes and these may affect the way in which they can be combined. Case studies may provide more insight in the use of different game elements in a Holodeck and on the situations in which digital simulation or real-world simulation should be used.

8.4 Recommendations

Based on this research and the current position of serious gaming and the Holodeck concept in GPR, the following recommendations can be made:

- Both the concept of serious gaming and the Holodeck have now been explored and documented in theory, as well as studied in a small number of prototypes and use cases. The organization should now try to find a number of concrete business cases in which their usability should be further tested and demonstrated.
- GPR should formulate clear purposes for any serious game or Holodeck that is to be developed and identify methods for the demonstration of their effectiveness at an early stage. This should increase the overall support for their use in the organization and may overcome any skepticism.
- As was already suggested by Zimmerman [47] in previous research, GPR should acquire expertise in the area of game design if they want to develop serious games themselves.

Appendix A – Hardware that may be used in a Holodeck and its estimated costs

This table features hardware equipment that may be used in a Holodeck, containing some standard equipment and some examples of high tech equipment that may be used in such an environment. A global indication of their prices is also presented.

Hardware	**Estimated costs**
Computers	
- PC (excluding monitor)	€ 400 - € 900
- Notebook	€ 600 - € 900
Central displays	
- Beamer + projection screen	€ 800 - € 2,300
- LCD TV (32" – 37")	€ 600 - € 1,800
- VisionDome 2 (2.2 m diameter semi-sphere display)	U.S. $ 33,500 – U.S. $ 68,900*
- Resolia LED billboard display monitor (140")	U.S. $ 399,000*
Input & output devices	
- Keyboard	€ 15 - € 60
- Mouse	€ 10 - € 40
- Monitor (19" TFT)	€ 120 - € 200
- Speakers (2.0)	€ 15 - € 50
- Speakers (5.1)	€ 60 - € 120
Phantom Omni (haptic device used at T-Xchange)	U.S. $ 2,400*
Reflection facilities	
- Whiteboard (100 * 150 cm)	€ 110
- Flip-over	€ 70 - € 220
- Markers	€ 1.50 - € 4.00
- Webcam	€ 20 - € 60
- Digital camera	€ 200 - € 500
Furniture and decorations	
(Bar) stool	€ 15 - € 50
Work lamp	€ 10 - € 30
Rug (round, 70 cm diameter)	€ 7.00

** May vary per country*

Costs have been estimated based on prices found at Block.nl [7], *Mycom.nl* [28], *Mitsubishi-megaview.com* [25], *vrealities.com* [43], *Sensable.com* [37], *Beamerspecialst.nl* [4], *Officeshopper.nl* [31] *and Ikea.nl* [14] *during October 2008.*

Appendix B – Interview with Martin de Haas on the Holodeck concept

This is a report of an interview held with Martin de Haas, the inventor of the Holodeck concept at GPR. It was held to acquire a more formal definition of the Holodeck concept and its purposes, next to any informal interviews and discussions that were held with De Haas during this research. The interview was conducted 8 June, 2008.

Where did the idea of a Holodeck originate from?

> *The idea originated from the observation that during the development process of a new system, or during change management, there is often a big gap between how things are and how they should be. This led to the idea that it was necessary to make ideas and concepts less abstract and far more explicit, to prevent misunderstandings in communication. If something can be simulated with a prototype everybody will be talking about the same concepts, they actually experience what is meant. To be able to determine whether something works the way it should work or not, it will have to be used and tested in the environment for which it is intended. This led to the idea of simulating such a work environment, a Holodeck.*
> *Another reason for the development of the concept of a Holodeck was my observation that administrators at GPR often had a very poor idea of what the applications they were managing were used for. Although I can't back this up, it is my believe that during development and change management, a lot of time, about 70%, is spent on determining what a system needs to do. If administrators would look at existing systems instead of starting from scratch, I believe that this percentage could be reduced to less than 50%. If one looks at existing applications, one can immediately see what is or isn't good and what should be changed. A Holodeck that could simulate existing solutions and possible future ones could eliminate the need for expensive, abstract thinkers. Administrators will be able to assist in determining possible solutions since they will be able to understand what a system is used for and should be able to do.*

How would you describe the purpose or purposes of the Holodeck concept?

> *The Holodeck can have a number of purposes:*
> 1. *Making visible how applications are used and what can be done with them.*
> 2. *Visualising alternative directions for solutions. (Supporting strategical decision making.)*
> 3. *Design instrument: What does or doesn't work and what could or should be changed?*
> 4. *Instrument for training*
> 5. *Supporting marketing/sales: A Holodeck can aid in visualising and determining alternative solutions.*
> 6. *Optimizing processes: How can the available system be used in an optimal way?*
> 7. *Instrument for definition: Determining what's required by simulation.*

8. *Assigning value: By determining how the addition of a certain component improves the work within a simulated Holodeck environment one can determine the benefits, and not just the costs, of that component. It allows for the allocation of value to IT.*
9. *Creating a business case: By developing a small scale, but fully functional prototype within a Holodeck environment it becomes an easy task to determine the benefits and costs of implementing that system on a larger scale.*
10. *Supporting change management: Creating support and acceptance within the community of users. People get a clear idea of what the changes will look like and get the idea that they are given enough opportunity for input and feedback. Sometimes the way in which a system is used should be changed; in this case, a paradigm shift is required. Both a practical and an emotional shift may be required; a Holodeck can be designed to support both kinds of change. The creation of the HKU was designed to accomplish the emotional shift.*
11. *Creating expectations: Show what will be possible at a minimum by letting people experiment with prototypes during development.*

What different forms may a Holodeck take to support these purposes?

A Holodeck may be an environment for experimentation, experiencing or simulation. Besides this, a Holodeck may also be designed to work at an emotional level, dealing with essences and paradigm shifts. This causes people to let go of their normal thinking patterns and is intended to let them look at a "reality" in a different way. This kind of experience, like the HKU experience, is actually not a Holodeck but a supporting tool.

Where did the idea to use serious gaming within the Holodeck originate from?

Within the Business Innovation department research was already being done into serious gaming. This seemed useful because games allow not only for the simulation of things, but also provide the opportunity to interact and experiment with these simulations.
The goals of a Holodeck can be reached effectively with the aid of serious gaming because it:

- *can create a deeper learning experience: games can provide guidance and set goals, forcing people to actually start doing things and experience. Games can also be used to guide the player in order to make sure he has worked with all different aspects of the simulation at the end of the game.*
- *can make it easier to separate players from their normal reality and way of thinking and open their minds for new ones.*
- *can make the Holodeck sessions more interesting and attractive.*

In what way do you expect serious gaming to be able to support a Holodeck in its various forms and in what way do you expect a Holodeck to be able to support a serious game?

> *The original idea for the Holodeck was to use two large monitors and a game console. A game master could then introduce changes to the Holodeck environment by changing what is displayed on the monitors, appearing on the monitors to give instructions, or by making a phone call for instance. In that way, the game master could control and react to what happens on the Holodeck.*
> *More generally, a Holodeck engages people in a different environment, assigning them certain roles, similar to how it's done in many video games.*
> *Through this, participation in the Holodeck experience becomes a sort of stand-up acting.*
> *Furthermore, the learning experience and recognisability of a game can also be improved by making a simulation as realistic as possible. This should include irrelevant details, just to stimulate the submersion of the player into the simulation on an emotional level.*
> *A Holodeck also allows a group op people to share a common experience.*

How would you define the minimal form of a Holodeck? What minimal criteria should be met for an environment to qualify as a Holodeck?

> *In its minimal form a Holodeck is a work environment that allows for the simulation of reality, guided by some form of instruction. By adding instructions, one can make sure a certain program is followed and all important aspects of working/playing with the simulation are dealt with. A Holodeck should always engage someone in a different reality, otherwise, the learning experience will be too limited.*

Are there any additional and optional elements which a Holodeck may contain?

> *Another element of a Holodeck is the support of group experiences. Most of the goals mentioned earlier are already based on the assumption that the Holodeck is used in this way.*
> *Another element that may extend the minimal form is gaming. Although work and a script that guides the users through different aspects of a simulation already contain a number of aspects of gaming, there is plenty of room for extension.*

What general definition would you like to use for the Holodeck concept?

> *An environment in which realities of a complex nature, both existing realities and alternative realities, can be simulated.*

References

[1] Abt, C.C. (1987), *Serious Games*. University Press of America, Lanham, MD.

[2] Aldrich, C. (2004), *Simulations and the Future of Learning*. Pfeiffer, San Francisco, CA.

[3] Amory, A., Naicker, K., Vincent, J. & Adams, C. (1999), The use of computer games as an educational tool: identification of appropriate game types and game elements. *British Journal of Educational Technology: 30*, 4, 311-321.

[4] Beamerspecialist (October 2008), *De Beamer Specialist – Alles over Beamers*. (*http://www.beamerspecialist.nl/*)

[5] Beck, J.C. & Wade, M. (2004), *Got Game: How the Gamer Generation Is Reshaping Business Forever*. Harvard Business School Press, Boston, MA.

[6] Berry, D. & Broadbent, D. (1988), Interactive tasks and the implicit-explicit distinction, *British Journal of Psychology*, *79*, 251-272.

[7] Block (October 2008), *Block Electrostore Online Shop*. (*http://www.block.nl/*)

[8] Van Boxtel, C., Van der Linden, J.L. & Kanselaar, G. (2000), Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction, 10, 4*, 311-330.

[9] Csikszentmihalyi, M. (1990), *Flow: The Psychology of Optimal Experience*. Harper & Row, New York.

[10] E-Semble (August 2008), *E-Semble. Simulation technology for safety and security*. (*http://www.e-semble.com/esemble/index.php?t=uk*)

[11] Gee, J.P. (2003), *What Video Games Have to Teach Us About Learning and Literacy*. Palgrave Macmillan, New York.

[12] Herz, J.C. (1997), *Joystick Nation*. Brown & Company, Little.

[13] Huizinga, J. (1955), *Homo Ludens*. The Beacon Press, Boston, MA.

[14] IKEA (October 2008), *IKEA Nederland*. (*http://www.ikea.com/nl/nl/*)

[15] Jamornmann, U. (2004), Techniques for Assessing Students' eLearning Achievement. *International Journal of The Computer, the Internet and Management, 12*, 2, 26-31.

[16] Jong, T. de & van Joolingen, W.R. (1998), Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68*, 179-202.

[17] Klawe, M.M. & Phillips, E. (1995), A classroom study: Electorinc games engange children as researchers. *Proceedings of Computer Support for Collaborative Learning '95 (CSCL)*, Bloomington, Indiana. (*http://www.cs.ubc.ca/nest/egems/reports/classroom.doc*)

[18] Lederman, L.C. (1992), Debriefing: Toward a systematic assessment of theory and practice. *Simulation & Gaming, 24*, 2, 145-160.

[19] Leemkuil, H. (2006), *Is it all in the game? Learner support in an educational knowledge management simulation game*. PhD thesis, University of Twente.

[20] Malone, T.W. (1980), *What Makes Things Fun to Learn? A study of intrinsically motivating computer games*. Xerox, Palo Alto.

[21] Malone, T.W. (1981), Toward a theory of intrinsically motivating instruction. *Cognitive Science, 4*, 333–369.

[22] McFarlane, A., Sparrowhawk, A. & Heald, Y. (2002), *Report on the educational use of games*. TEEM (Teachers evaluating educational multimedia), Cambridge.

[23] Michael, D. & Chen, S. (2005), Proof of Learning: Assessment in Serious Games, *Gamasutra*. (*http://www.gamasutra.com/features/20051019/chen_01.shtml*)

[24] Michael, D. & Chen, S. (2006), *Serious Games – Games That Educate, Train, and Inform*. Thomson Course Technology PTR, Boston, MA.

[25] Mitsubishi-megaview (October 2008), *Mitsubishi drops price on Resolia 140" LED screen by $200,000*. (*http://www.mitsubishi-megaview.com/pdf/Mitsubishi_Resolia_Price_Drop.pdf*)

[26] Mödritscher, F., Spiel, S.D. & Garcia-Barrios, V.M. (2006), *Assessment in E-Learning Environments: A Comparison of three Methods*. Graz University of Technology, Austria.

[27] Munro, A., Fehling, M.R. & Towne, D.M. (1985), Instructional instrusiveness in dynamic simulation training. *Journal of computer based instruction, 12*, 2, 50-53.

[28] Mycom (October 2008), *ComputerWinkel MyCom*. (*http://www.mycom.nl/*)

[29] Nickols, F. (2000), The knowledge in knowledge management. In Cortada, J. and Woods, J.A. (ed.), *The knowledge management yearbook 2000-2001*. Butterworth-Heinemann, Boston, MA.

[30] Norman, D.A. (1993), *Things that make us smart. Defending human attributes in the age of the machine*. Addison-Wesley Publishing Company, Reading, MA.

[31] Officeshopper (October 2008), *Officeshopper.nl – Kantoorartikelen.* (*http://www.officeshopper.nl/*)

[32] Peters, V.A.M. & Vissers, G.A.N. (2004), A simple classification model for debriefing simulation games. *Simulation & Gaming: An international Journal, 35*, 1, 70-84.

[33] Prensky, M. (2001), *Digital game-based learning*. Mc Graw-Hill, New York.

[34] Reiser, B.J. (2002), Why Scaffolding Should Sometimes Make Tasks More Difficult for Learners. In Stahl, G. (ed.), *Computer support for collaborative Learning foundations for a CSCL community. Proceedings of CSCL 2002, Boulder, Colorado, USA (January 7-11, 2002), 255-264*. Lawrence Erlbaum Associates, Inc., Hillsdale, New Jersey.

[35] Rhodes, T. (2008), How to Build a Holodeck. *The Escapist*. (*http://www.escapistmagazine.com/articles/view/issues/issue_141/3028-How-to-Build-a-Holodeck*)

[36] Rieber, L.P. (1996), Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research & Development, 44*, 2, 43-58.

[37] Sensable (October 2008), *The PHANTOM Omni Developer Kit*. (*http://www.sensable.com/phantom-omni-developer-kit.htm*)

[38] Taatgen, N.A. (1999), *Learning without limits. From Problem Solving towards a Unified Theory of Learning*. PhD Thesis, University of Groningen.

[39] T-Xchange (August 2008), *T-Xchange, Engineering Innovation*. (*http://www.txchange.nl/*)

[40] Universiteit Twente (2006), *Da Vinci, The challenge 2006*. (*http://www.utwente.nl/wetenschapsquiz/locatie/*)

[41] Veerman, A. & Veldhuis-Diermanse, E. (2001), Collaborative learning through computer-mediated communication in academic education. In: Dillenbourg, P., Eurelings, A. & Hakkarainen, K. *European perspectives on computer supported collaborative learning. Proceedings of the first European conference on computer supported collaborative learning*. Maastricht McLuhan Institute, Maastricht.

[42] VirtuSphere (October 2008), *VIRTUSPHERE – a new locomotion technology for immersing in virtual reality*. (*http://www.virtusphere.com/*)

[43] Vrealities (October 2008), *VisionDome 2 – Virtual Reality Dome*. (*http://www.vrealities.com/visiondome2.html*)

[44] Wikipedia (August 2008), Holodeck. *Wikipedia, The Free Encyclopedia*. (*http://en.wikipedia.org/wiki/Holodeck*)

[45] Wikipedia (April 2008), Serious_game. *Wikipedia, The Free Encyclopedia*. (*http://en.wikipedia.org/wiki/Serious_game*)

[46] Wikipedia (August 2008), Simulation. *Wikipedia, The Free Encyclopedia*. (*http://en.wikipedia.org/wiki/Simulation*)

[47] Zimmerman, J. (2007), *Toepassen van "serious games" ter ondersteuning van de opleiding binnen het bedrijfsproces ICT service management.* Master Thesis, University of Twente.