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1. Introduction

1.1 Context

At the start of this research Getronics PinkRoccade (GPR) was currently 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 serious gaming, a Holodeck and the possibilities for 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 support the exploration of a simulation by providing clear goals, offering guidance through rules and a storyline and may enhance the overall attractiveness of the experience. 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. 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 goals 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 to measure 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 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 can 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 shall be discussed that are relevant for learning with serious games.

2.1 Defining serious games

A short definition of serious games can be found at Wikipedia […], 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 […], 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. For this, 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 […], 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 […] uses the following definition of game, based on an earlier definition of Dempsey et al. […], in which most of the elements that Prensky 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 […] give a definition that includes some other, but also some similar characteristics, based on a list of six characteristics of "play" given by Huizinga […]:

> *"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 […], 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. The focus in this document however 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 from 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 […] point out, be used for other things such as the promotion of products or creating awareness for a certain subject. The only real limitation is that the goal of a serious game has to be "serious".

To summarise the information above I would like to introduce the following definition of a serious game, as I will use it 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 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 be 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 […] and are used by Zimmerman […], 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 […] distinguishes three different types of goals, which can be used in combination:

- 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 […nr 28 van Zimmerman] 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 the 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 […] 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 […] 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. <examples?>

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 working 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, which 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, to allow the players to learn the functioning of the underlying model. Abt […] 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 cointain 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 […] 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 each player plays in his 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 is always 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 a certain goal 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 […] 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 […], developers should make sure that the players understand the working of the underlying model correctly and there will 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, such as 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 […]. 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 […], 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. […] 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 […Zimmerman, ref28] and Armorty et al. […] 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 […], 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 […], 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 other things are no longer relevant. Based on this theory, Malone […Zimmerman, ref27] 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 […].

- The activity should be structured in a way that allows the player to adjust the difficulty of the game so that the challenge is 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 extend 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 […] 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 […] 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 it's 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 […] 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 […], or Zimmerman […] or Herz […], 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

2.3 Theories of learning and serious gaming

In most cases one of the goals of serious games will be to teach something to the 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 […] 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 […] 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 […] 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 differnt kinds of knowledge a distintinction can be made between different ways of information processing that people use as well. Leemkuil […] distinguishes, based on a review of the research of Berry and Broadbent […], Norman […] and Taatgen […], 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 […] 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 […] 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 […].
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 […] 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 […] gives of the work of Prensky […].

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 learned 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

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

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, that 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 en Wade […] 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 build 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 […] by mentioning the year 1975, the difference in the use of learning strategies will not always be this sharp in everyday life. Zimmerman 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 […] 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 […] 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 […] 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 […] 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, steepness of the descent, etcetera. By comparing this information from different landings players can discover new rules about how to proceed in 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 […] points to research of Munro, Fehling and Towne […], 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 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 advise 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 […] 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 learning environment has also been mentioned as one of the ways to encourage a reflective way of information processing, by Reiser […] 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 […], 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 […] 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 […] collaboration can provoke activity, make learning more realistic and stimulate motivation. Leemkuil […] states that people in collaborative settings are "forced" to share perspectives, experiences, insights and understandings. According to Zimmerman […] 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 […] provides the following distinction based on that given by Van Boxtel […]:

> "*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 from Klawe and Philips […] 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 […] 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 […] 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 them 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 […] 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 […] 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."* [M&C 2]

Michael and Chen […1 & …2] 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 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 to 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 […1] "*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. […], 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 […2] 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 […2] 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 […2] 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 […] 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 […2] 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 […1] 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 […]. In this game, in which the 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 and 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 […2] 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 […2], "*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 […1] suggest that for serious games, both pre-game and post-game testing should take place. The reason for this is that the efficacy 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.

3.3.2 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 […1 & …2], will now be discussed.

Game levels
Many entertainment games are divided in levels: different missions the players have complete, different areas the players have to traverse, etcetera, arranged in a certain order. Michael and Chen […1] 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 […2] 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 […2], "*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 […] 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 […2] 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 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. This form of learning currently is far from common practice in the field of serious gaming, but, as Michael and Chen 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 […2] 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 […2], 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 […2] 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 […2], "*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 […2], 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 […2] point out, modern 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 […2], "*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 learned. "*The more data is available, the less subjective that evaluation needs to be,*" as it is said by Michael and Chen […2].

Furthermore, teacher evaluation can also include observation. Again, entertainment games already provide some useful techniques. As Michael and Chen […1] 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 […2], 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 is still 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 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, <other examples>. 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 were 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 x.x. 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 allow 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.

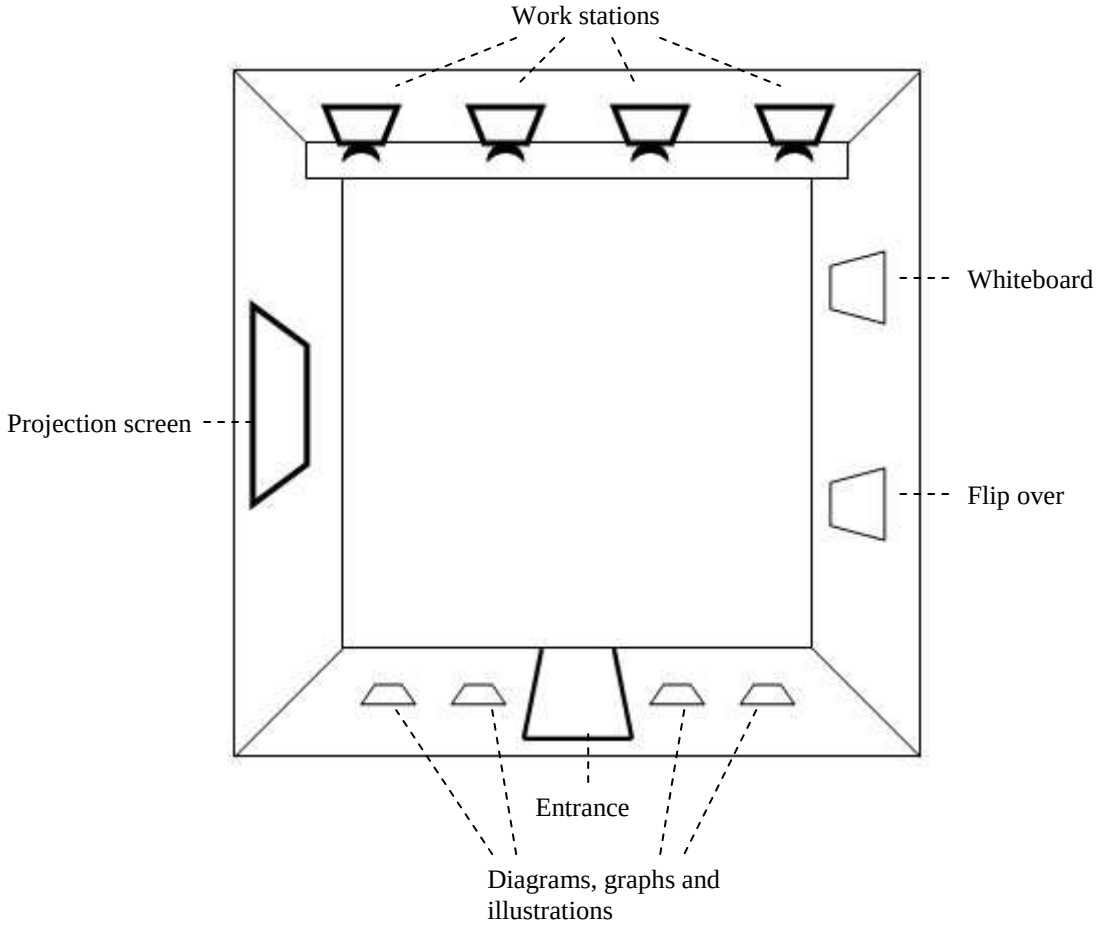

Figure x.x - Layout of the Holodeck and its various tools as it was used during PoCs at the Belastingdienst

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 briefly discussed, supported by some images to give a visual impression.

4.2.1 T-Xchange

T-Xchange […] 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 x.x and x.y.
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, design a new residential district and as a tool for product design.

Figure x.x – The T-Xchange Cell in Twente, a high tech simulation environment

Figure x.y – Details of the T-Xchange Cell

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 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, which means they might be talking about different things without realising they are, because the terms and models they use 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.
The possibilities for the use of a Holodeck are not just limited to requirements engineering however, a Holodeck may be used for other purposes as well. Besides this, it is not just limited to the domain of IT, but 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 A, 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 excisting 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, processess and collaborations not necesarrily 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 in 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 better or more efficiently and 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 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 works 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 … and explained further below:

1. The excisting "reality", the current situation, is analysed to identify the problems that excist 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 excisting 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, 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.

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.

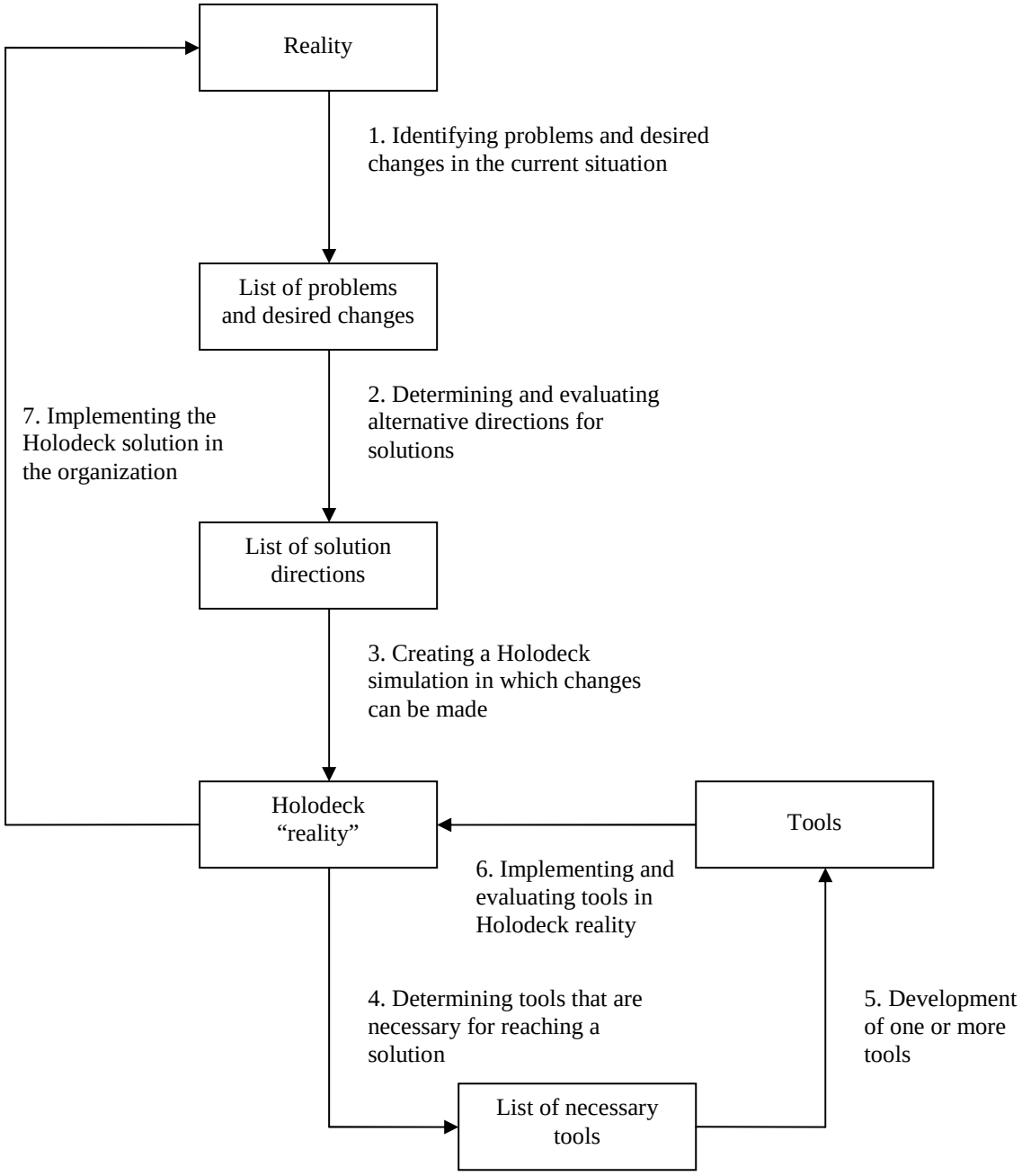

Figure x.x – The way in which a Holodeck may be used to support various goals during a process of adaptation or change.

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 x.x, 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 phase
4. <terugkoppeling> and abstraction

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 presented with the necessary background information, information about the progress that has been made since the last sesson, 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.

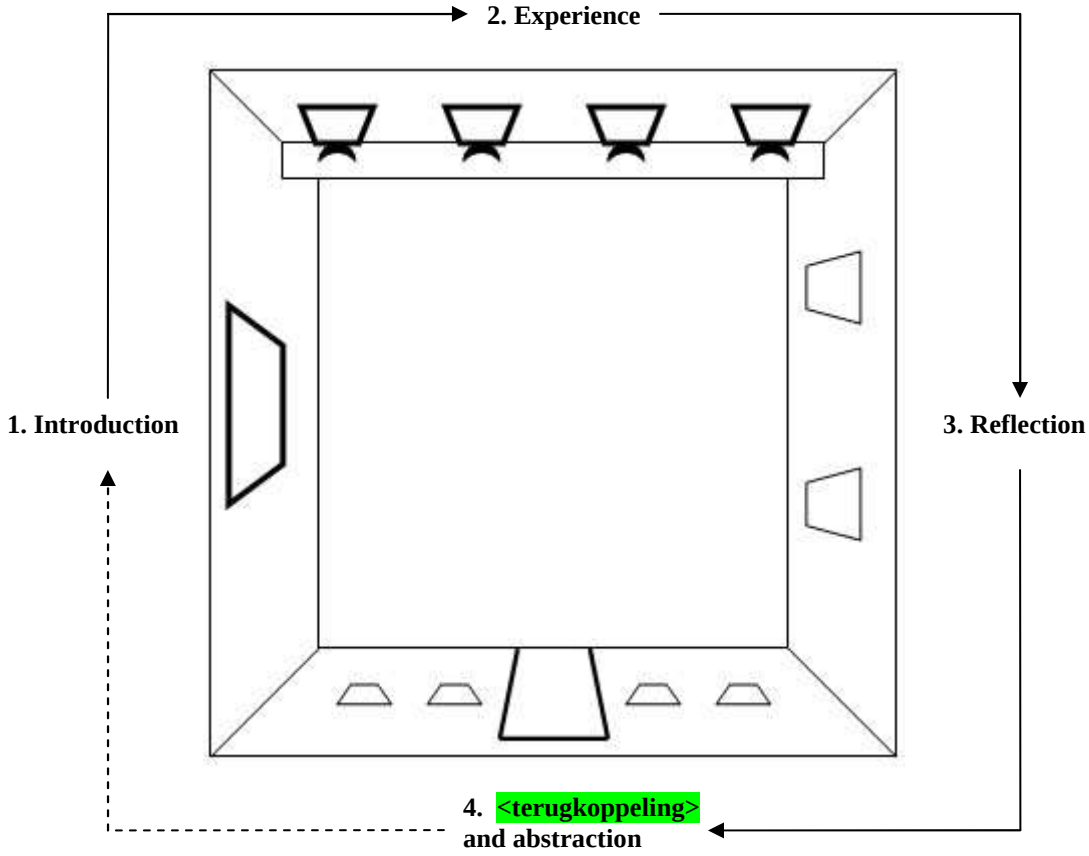

Figure x.x - Layout of the Holodeck as it was used during PoCs at the Belastingdienst, displaying the different phases of a Holodeck session.

3. Reflection
During the reflection phase, information is gathered on the experiences of participants during the previous phase. Participants get the opportunity to provide feedback and during group discussions, they can determine what implications the current system has on the work process, whether such a process offers a "workable" situation and what could or should be improved in order to reach better results.
The Holodeck environment provides tools for facilitating such discussion in the form of a whiteboard and a flip over. The process should be guided by a facilitator.

4. <terugkoppeling> and abstraction (moet nog helderder)
Finally, the session may be closed by a moment of <terugkoppeling> and abstraction. In this phase, the facilitator can relate all previous experiences to central issues that are difficult to express.
The Holodeck environment can support this process with a number of images or models that catch the essence of these concepts in a symbolic way.

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 acieved by the new way of working. This expert is of importance during the introduction phase and may offer advise 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 phase and the <terugkoppeling> and abstraction phase. The domain expert and expert on tools should also be available during the reflection phase, to receive feedback and deal with questions that touch on details within their areas of expertice.
- *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 <terugkoppeling> and abstraction phase.
- *Simulation/serious game developer*: Someone who can develop a simulation or serious game that can be used during the experience phase. It requires expertice 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 expertice. 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.
The realities simulated in a Holodeck can be both existing realities and realities that could exist in a hypothetical sense.

Simulation
According to Wikipedia […3], "*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 in 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 the simulated reality. They can perform certain actions and make certain changes to discover how the simulation behaves and responds to them.

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 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 4.1.1 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 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, 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, discussed in section …. 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. In section 6.1, the added value serious gaming might provide to a Holodeck will be discusses, whereas in section 6.2, the discussion will be reversed and the added value a Holodeck might provide to serious gaming will be examined. Finally, in section 6.3, the discussion will focus on the effects a Holodeck may have on the possibilities for assessment and the measurement of effectiveness of a serious game, as they were discussed in chapter 3.

6.1 What added value can serious gaming offer in a Holodeck setting?

The use of serious gaming as a learning or communication tool has been advocated by many writers. Abt […], 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, starting by looking at the use of game elements.

6.1.1 The use of game elements

In section 2.2.1, the following six elements of games were identified: a challenging goal, rules and an underlying model, competition, interaction, uncertainty and situatedness and story. These elements may be used as a guide in the discussion of what added value serious gaming can provide to a Holodeck.
Even in its barest form, a Holodeck which complies with the definition in section 4.1.3 will already contain the following of these game elements to a certain extend:

- Interaction
- Rules and an underlying model
- Situatedness and story

Interaction
An important part of the Holodeck concept is to let people work and interact with a software application, a certain work setting, or some other kind of simulation themselves. In order to do this, (a prototype or partially functional version of) the application is provided to experiment with, or the Holodeck offers the tools that allows its participants to simulate a

certain work setting or other “reality”. In each case, players should be able to get feedback about the effects of their actions on the simulation. Computer simulations may be a good tool to provide such feedback. They can visualise effects of certain actions in a clear way, provide performance metrics and allow for experimentation without any negative consequences in the real world. T-Xchange uses computer simulation, or serious gaming, as they call it themselves, in this way.

Rules and an underlying model

A Holodeck will always contain an underlying model of what is being simulated. Without this, it would be impossible to determine how a simulation functions and what the reactions to the actions of its participants should be. Computer technology may be used to quickly calculate and simulate the behavior of certain models, while other models, such as social relationships, can best be simulated in a non-digital way.

Rules may be present in a Holodeck as well. These can include simple rules concerning the division in groups in which participants will experiment with a simulation and rules concerning the interaction that is allowed between these groups, but they can also include rules that impose restrictions on the ways in which participants may experiment with a simulation itself. These may be used to forbid the use of certain tools or limit the range of possible solutions in order to force people to search for alternative solutions in other directions, possibly forcing them to think out of the box. An example is this is introducing a rule that prevents the use of IT as a tool in a session with IT specialists to let them discover whether there are other, perhaps even better alternatives.
If the game element competition is added to a Holodeck additional rules to guide this competition will have to be established as well.

Situatedness and story

To separate people from their normal thinking patterns, so it becomes easier for them to come up with new and creative solutions, a Holodeck can be set up in such a way that it offers an environment and experience that differ from its participants’ normal reality. It may also be used to simulate a specific reality, in which the participants are assigned a certain role, such as the end users of a certain information system the participants themselves are developing. Such realities may be created by the environment, the events that occur and the goals and tasks participants are assigned.

To make sure participants experience all relevant aspects of a simulation during a Holodeck session, a number of fictual situations may be integrated into the simulation covering these different aspects, such as certain problems that need to be solved. The participants can then be guided through these situations and tasks by some sort of manual or walkthrough. This can be seen as a limited form of a story.
Of course, following a manual does not make for a very interesting story. Serious game technology may be used to sketch a clear and more interesting storyline, which may present the broader context of a task, underline the roles of participants and bring other characters to life in a virtual form, such as customers who are in dire need of the participants help. Furthermore, game technology may be used to create a digital representation of the fantasy world that is created, as it is done at T-Xchange, making the fantasy as complete and engaging as possible.

There are also a number of game elements that are not part of a Holodeck by definition, or only in a limited way, but which might provide added value to it should they be integrated. Thsese are:

- A challenging goal
- Competition
- Uncertainty

A challenging goal

In section 2.2.1, three different types of goals that players might have were identified: solving a certain problem or a series of problems, reaching a higher level of skill or efficiency and beating a group of other players. Whether these types of goals can be used in a Holodeck setting depends on the purposes for which the Holodeck is used.

When a Holodeck is used to design a solution to a complex problem, solving this problem already is a challenge in itself and there is no point in introducing other problems that need to be dealt with. If a Holodeck is used for training purposes however, adding a series of challenges that need to be overcome may be a good way to introduce participants to all relevant aspects they need to learn and require them to learn how to solve them.

Improving previous pernamce is already a goal in process optimalization and in an iterative design process as well. Computer simulations may allow for accurate tracking of performance metrics and visualization of these indicators, which might increase the sense of challenge.

In design situations, beating a group of other players may be added as a goal by splitting up the group of participants into a number of subgroups and letting them compete against each other to achieve the best reslutls. This can result in an increased sense of challenge and a wider variety of ideas. At the same time, smaller subgroups might reach less optimal results because they are lacking certain stakeholders and may be too competitively oriented towards other groups, failing to see the potential of the ideas of others, or being reluctant to continue working with a chosen solution because they still feel their own solution is the better one.

In training situations, the goal of beating a group of other players may serve as a useful stimulation for trainees to give the best they've got. Setting up some sort of highscore list for instance will increase the sense of challenge for a lot of people.

Competition

The following four forms of competition were identified in section 2.2.1: beating the system, beating yourself by improving your performance in the next game round, beating other players in a direct confrontation and beating other players by performing better than they did in previous rounds. These forms of competition show a clear relationship with the three types of goals mentioned earlier. Therefore, much of what was said about these goals in relation to a Holodeck also holds for competition. Competition may increase the sense of challenge and motivate participants to try hard and enjoy themselves in the process. Note, however, that not every person will show a positive response to competition, as was explained in section 2.3.3.

Uncertainty

There are a number of forms of uncertainty that may contribute to the challenge and variation in a game, as identified in section 2.2.1: uncertainty about the actions of other players or those of the system, unexpected events that are introduced into the game environment, chance

or coincidence and the fact that not the entire game environment, or the underlying model is made known to the player at the start of a game.
In situations where a Holodeck is used to find a solution to a complex problem, the nature of the solution will be unknown, which is a form of uncertainty in itself, but not one that seems to fit within the list above. It is, at least, a form of uncertainty that is already present and not something that could be added as a game element to add variation and challenge.
When a Holodeck is used for training purposes there are opportunities for using uncertainty as a game element. Unexpected events that are introduced into a sequence of tasks every once in a while can keep the trainee sharp, add variation and, if properly used, add challenge.

6.1.2 Added value

Based on the discussion of the possibilities for the use of game elements in a Holodeck a number of ways in which the use of a serious game, or elements of a serious game, may provide added value to a Holodeck can be identified. These will be discussed in the text below:

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, without any risk of damage in the real world.

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 technogoly 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 also the attractiveness of a Holodeck simulation and hence the engagement in the fantasy that is created.

Guidance and story
Serious gaming techniques may be used to provide a story that can guide participants through a number of relevant aspects of a simulation. A story can introduce these aspects and put them in context. For example, a story may tell what events led to a task that needs to be performed in a training situation and explain the consequences of performing this task after its completion. A story can also be used to link a number of different interaction moments together, explaining their relation and engaging participants further in a continuous fantasy. A story 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.

Attractiveness

Games have a number of characteristics that make them attractive. In section 2.2.2, the following of these characteristics were identified: fantasy, challenge, curiosity and engagement caused by flow. Visualisation of an alternative reality by means of digital representations and the introduction of a story may prickle the fantasy, while goals, competition and uncertainty may cause challenge. Curiosity can be reached by both uncertainty and story. Engagement has been discussed in more detail in section 2.2.2.
As was identified in the previous section, many of these elements that cause attractiveness may be hard to incorporate into a design process, while a Holodeck that is used for training purposes is in a better position to make use of these elements. Attractiveness will enhance the active participation of participants.

Creating a full serious game containing all six game elements may not be possible in all situations in which a Holodeck might be used, but neither is this necessary in every situation. In training situations, a complete serious game may be designed that can be used within a Holodeck environment, but for other purposes, such as design support, a Holodeck may simply implement only a number of these elements, creating game-like situations where appropriate, making use of the advantages described above.
The extent to which game elements and game technology may be used also depends on the nature of the problem or solution that is concerned. Rich 3D visualizations such as the ones that are used at T-Xchange can be highly suited for creating virtual worlds and the design of physical products, but may be less useful when dealing with a large administrative system.

6.2 What added value can a Holodeck offer to serious gaming?

The question dealt with in the previous section will now be reversed and the ways in which the setup of a Holodeck environment and a Holodeck session may provide added value to serious gaming will be examined. Again, this discussion shall be started by looking at the use of game elements.

6.2.1 Changes in the use of game elements

In section 2.2.1 of this text six basic elements of a game have been discussed: a challenging goal, rules and an underlying model, competition, interaction, uncertainty and situatedness and story.
Combining a serious game with a Holodeck will provide the opportunity for enhancements, or at least changes, to the way in which a number of these elements are given shape. These changes will now be discussed for those elements that may be affected by the addition of a Holodeck to a serious game, these are:

- Situatedness and story
- Interaction
- Rules and an underlying model

Situatedness and story
The fantasy world that is created in a serious game, or "reality" as it was called in the discussion of the Holodeck concept, can be offered in a Holodeck environment in two different ways:

- The Holodeck environment can provide the tools with which a virtual "reality" can be created, such as monitors and a set of speakers. In this case, the game world will only exist in a digital form.
- The Holodeck environment can be used as a part of the fantasy, in which case the environment itself becomes the game world in which the game is played.

This second way of using a Holodeck environment will have important implications for a serious game. First of all, it means that players are no longer only mentally present in a game environment, but physically as well. This means that certain aspects of their physical behavior may suddenly become of importance in the game, such as their position in the environment, which determines what part of the environment they can interact with at a certain point in time, but also their physical strength, speed and hand-eye-coordination (other than moving a mouse or pushing buttons) may suddenly become of importance.
Furthermore, while in regular video games the mental presence of the player is often accomplished by means of an avatar (a virtual character that the player can control), in a Holodeck environment the players may become the main character of the story themselves, both mentally and physically. Of course, the could still dress up and pretend to be someone else, like in a real life role playing game (in fact, a Holodeck game may become one), but the difference between this and controlling a virtual hero is apparent.
There are also a number of video games that do not use avatars. Some of these games may make use of a Holodeck without creating a specific identity for the player, such as simple puzzle games. Other games, such as most strategy games (and simulation games like Sim City

and Rollercoaster Tycoon), do have a certain role for the players to play, but this character is often not present in the game world. Players are addressed as something like “general” by game characters, but look down on the game environment from a bird eye point of view and can construct buildings and move armies with just one or two mouse clicks. Sometimes such games are called “god games” because of this. Of course, such interaction is hard to translate to a person playing a general in a real world environment. Therefore, such a Holodeck environment would have to be adapted to such a role by offering more appropriate “instruments” for interaction and, in the case of strategy games, could for instance be adapted to a command center. Whether the creation of such an environment is desirable is another question. The experience will likely be very different and players may learn different things and loose the advantages the overview and simplified interaction god games may provide. Although bringing a game world into a real world environment may seem attractive it should also be useful.

Interaction

Another important possibility of a Holodeck is its ability to change the way in which interaction takes place within a serious game.Within a Holodeck environment, players of a serious game are no longer limited to the standard input devices and output devices of a PC or game console, such as mouse and keyboard and a single monitor. Instead, a wide range of other devices can be used within a Holodeck setting as well, depending on the type of Holodeck. The easiest example, although somewhat outside the scope of the term “Holodeck” as it was defined earlier in this text, is that of a flight simulator. In this environment, a pilot is presented with a wide range of instruments, both for input and output, which one would normally find in a real 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, like …, or gloves with “*force feedback*” that can simulate physical forces and objects, like ….

But even in less technically advanced settings, a Holodeck allows its developers to introduce new ways of interaction to a serious game. In the case study that will be discussed later, nearly the entire room functions as either an input or an output device and there are many different forms of interaction. The lighting, for instance, will change a number of times as the Holodeck experience progresses, changing the atmosphere in the room and serving as an indication of success or failure. As another example, one of the tasks that “players” need to perform is forming a human chain between two points, after which a video fragment will be triggered by a number of sensors and the Holodeck experience continues.

This last example also introduces another important possibility that a Holodeck provides: collaboration. The experience will not continue unless people will work together to form the human chain. Another task in this Holodeck environment requires one player to watch a monitor displaying output, while another team member on the other side of the room is turning knobs in order to change this output. Communication is required in order to get this right.

While there are many video games that allow for or even require collaboration, examples such as the ones above illustrate that a Holodeck can provide other, more personal forms of collaboration as well.

Besides collaboration, there may be other forms of human interaction within a Holodeck as well. Since the Holodeck environment can be used as a part of the simulated “reality”, all interaction that takes place between people within this environment may become relevant to the game and a game may be designed in a way to employ this. Besides interaction between

players, one of the facilitators may also act as a “game master” and interact with the players in a certain role. He or she can then give guidance, help, or information to aid players or to add realism to certain aspects in a simulation that would normally require communication with people, such as customers. Human interaction does not have to be face-to-face, but might also occur through a phone that is placed somewhere in the environment. The discussion above can be summarized as follows:

- A Holodeck can add new forms of interaction to serious games by providing alternative devices for input and output.
- A Holodeck can provide a setting for human interaction between players, such as collaboration and interacting with a system as a group.
- A Holodeck can provide a setting for human interaction with a “game master” who is playing a certain role.

Rules and an underlying model
New forms of interaction that a Holodeck introduces to a serious game will require new rules and underlying models. New input devices can change the actions that are available to the players. They may limit the amount of available actions themselves, by the way in which they can be operated, but they can also have functionalities that may disrupt the game, in which case rules will be needed to limit the players in using these functionalities. For any form of input in a Holodeck, developers should consider when and how it can be used and set up rules where necessary.
New forms of interaction in a Holodeck will also have an effect on the underlying model of a game. They may require changes to deal with other types of input or to manage other types of output, such as the lights in the Holodeck environment of the case study mentioned earlier. New forms of interaction may also make it possible to develop an underlying model that could not have been developed for a regular serious game, because the model would require functionalities that could not be supported via normal forms of interaction.
Behavioral rules are another set of rules that may have to be revised, especially when multiple players are present at the Holodeck at the same time. If a number of competing players are close to each other in the same environment during the game, rules might be needed to restrict hindrance and to determine to what extend observing and copying the actions of other players is allowed. In case of a collaborative learning environment, restrictions might need to be placed on the extent to which players are allowed to help each other, to make sure that all players actually learn what they are supposed to learn themselves. While collaboration may be useful in a number of cases, players shouldn’t be able to succeed merely through the efforts of others.

6.2.2 Support of reflective learning

In section 2.4.4, six methods and tools that can support the use of a reflective learning strategy have been discussed, these were: *feedback*, *guidance*, *additional assignments*, *cooperation and collaboration*, *debriefing and group discussions* and *monitoring facilities*. Among these, there seem to be a number of methods and tools that can easily be supported by a Holodeck. Since a Holodeck already brings together a group of participants in a single environment, it becomes easier to let them cooperate and collaborate during the experience phase of a Holodeck session. Advantages that such collaboratin might bring have been discussed in section 2.4.4 of this text.

Another method that is clearly supported by a Holodeck environment is debriefing and group discussions. A Holodeck session already incorporates this method as a separate phase and the process is supported by tools as a whiteboard and flip over, as was discussed in section 5.3.1. Finally, guidance can be supported by the presence of experts on the problem domain and the tools that are used during a Holodeck session, who may offer guidance when appropriate. As was discussed in section 5.3.2, the concept of a Holodeck already assumes the presence of such experts.

6.2.3 Advantages provided by the change in the use of game elements

Based on the discussion above a number of ways can be identified in which a Holodeck might be used to provide added value to serious gaming. These will now be discussed.

Realism
The sense of realism of a serious game can be improved in a Holodeck. This may be achieved by the use of new (realistic) instruments for interaction, human interaction (role-playing) instead of articificial conversations with computer characters and the use of a Holodeck environment as part of the simulated "reality". A (proper) simulated environment in the real world will likely create a greater sense of realism than a simulation on a computer screen which will always seem "distant" to some extend.

Attractiveness
Although the hypothesis would have to be tested, *engagement* caused by *flow*, which was described as "a state in which a person is involved in a process in such a way that all other other things are no longer relevant" in section 2.2.2, would likely be easier to achieve if a person is submerged in an environment that is part of the game world and hence offers no distractions from outside the simulated "reality". *Fantasy*, another element that was identified as causing attractiveness, is also likely to be stimulated by such a surrounding environment. The uniqueness of such an environment is also likely to stimulate *curiosity*.

Support of reflective learning
A Holodeck provides a suitable environment for *collaboration* and *debriefing and group discussions*, which may be used to support a reflective learning strategy. *Guidance* may be offered by the experts that are present in a Holodeck that is set up in the way that was discussed in section 5.3.

Environment for surrounding training program
A Holodeck set up in the way that was discussed in section 5.3, may be suitable as an environment 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 as well.

The use of a Holodeck environment as a part of the game world may offer some problems or challenges to serious gaming as well. Some aspects of the game, such as human interaction,

may fall outside the control of a computer program and will have to be linked to the game in some other way, by observations of the game master for instance, who can then provide results or scores to the system through manual input. It may also be possible however, that interaction within the Holodeck environment cannot be combined with a computer program at all, or not in any practical way.

6.3 Does the use of a Holodeck require or facilitate other forms of assessment?

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