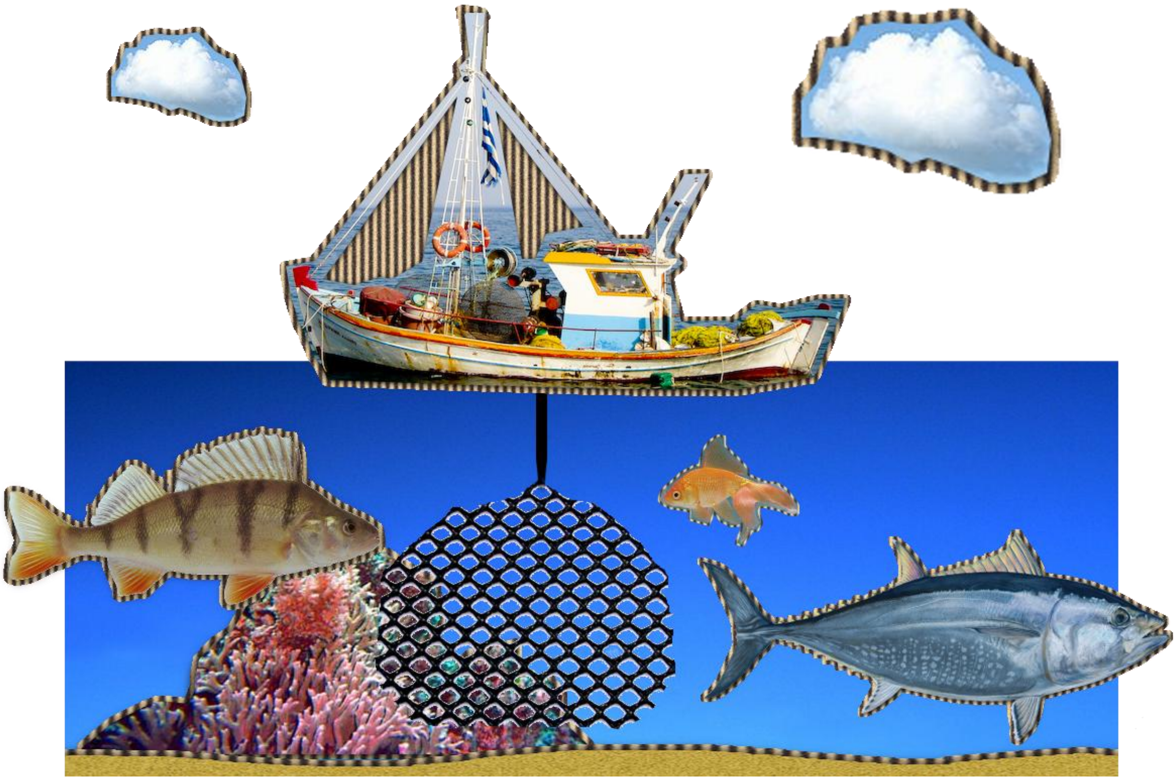
Let the game do the talking

The influence of explicitness and game behavior on comprehension in an educational computer game.



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Give a man a fish and you feed him for a day.
Teach a man to fish and you feed him for a lifetime.
– Chinese proverb

ABSTRACT

An endogenous educational game is a game where the educational content is integrated in the gameplay mechanics themselves, mostly in the form of a simulation. They rely on a constructivist approach to learning, where the learner constructs knowledge through concrete experiences. Endogenous educational games which are specifically developed for educational purposes mostly make this purpose explicit: they make it clear in advance what is about to be learned. This research tried to find out how such an explicit purpose influences the game behavior and comprehension by developing two versions of an endogenous educational game about overfishing, one with and one without an explicit purpose. It showed that children who played the explicit version got more shallow knowledge and showed more active game behavior. The players who showed more explorative game behavior acquired more deep knowledge about the game.

Foreword

As a gamer, I have always been interested in the possibilities of the medium other than being a fun diversion. In how games can tell good stories or communicate a message through the interaction with the game world. In searching a suitable subject for my graduation, this quickly lead me to educational games. Even nowadays there are still many games which want to convey a message by using a well-proved game concept with just a theme and some texts containing the actual message. The game The Seagull Strikes Back[1], developed for the WWF, is a striking example. It wants to convey an educational message about overfishing, but the game itself totally misses the point. The player controls a seagull and has to drop feces on fishing boats in order to prevent overfishing. About the real issue and mechanics behind overfishing it does not teach anything.

As I went deeper into the subject of educational games, it turned out luckily there are many researchers who think as well that such a seagull-game is not the right approach to games and education. But still, conveying a large part of the educational message through text, virtual teachers and other explicit messages seems the norm. Therefore I decided it would be interesting to look at how this explicitness influences the way the game is played. By focusing at the game itself instead of only at the educational results, the focus is more on media interaction than on educational design. "What does the game itself communicate?" became the central question.

Hopefully this thesis gives the reader some interesting thoughts about educational game design and will make people think more about what they communicate directly and when they "let the game do the talking".

And of course I would like to thank my committee members Frans van der Sluis, Betsy van Dijk and Anton Nijholt for the time and effort they put into giving feedback and sharing their thoughts on my research.

[1] See: http://assets.panda.org/custom/games/seagullstrikes/

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1 Introduction

It is easy to think of learning through video and computer games as a hype, as a novelty used to engage students who become bored by the usual text books and lectures. But games have more potential than that. Games can offer environments in which learners can freely experiment, which lead to concrete experiences which build a strong sense of relevance and engagement [Ege07, p. 197-198].

Learning is not just something which *can* be done with games, but instead one of the most prominent incentives to play games in general. The challenge games offer, an important attraction for nearly every game, comes from the ability of the player to learn new strategies or skills while playing and to apply those skills in order to proceed in the game [Cra84]. This is true even for most straightforward action games, from the classic *Space Invaders*[2] to the more recent *Call of Duty: Black Ops*[3]. Every time the player reaches a higher score or proceeds to the next level, he has learned to play the game even better.

Some even suggest that the way games let themselves get learned by players could be used as an inspiration for classroom teaching and other learning environments as well [Gee03]. For games, it is important that they get learned well, because players otherwise can get demotivated when they cannot overcome an obstacle. But at the same time they should have a certain level of complexity to remain fun and interesting for a long time, so *dumbing down* games is not always an option. Games solve this by providing the information needed at the right time and by providing challenges which are "on the edge of a player's competence" [Gee03], instead of on the level of the lowest common denominator.

The fact that learning is so inseparable from what a game is underlines the importance to explore the educational potential of computer games. Games can offer new, hands-on approaches to learning which set them apart from other media. The main difference between a normal game, with all of its learning qualities, and an educational game, is its subject matter. The player should not learn how to shoot aliens or fly a virtual spaceship, but something that is relevant and applicable as well outside the scope of the game itself.

But even though games and learning seem inseparable, at the same time the educational potential of videogames has not been fully utilized. According to Egenfeldt-Nielsen [Ege07, p197,198], this is caused by bad market conditions, the cultural perception of computer games and the current school structure, amongst other reasons. But as Egenfeldt-Nielsen points out as well, it is not a good idea to think about computer games as something that has the potential to *revolutionize* learning. There is

[2] Taito Corporation, 1987
[3] Activision Publishing, 2010

potential, but "[educational computer games] are more than anything else an extension of other human practices."

To estimate the quality of games as a learning tool, the focus has been on the learning results. By adding an extra level of explicitness to the game, learning results greatly improved [CZ04]. But herein lies the risk for the medium that the explicit messages themselves contain the learning content and that the game, with all of its learning qualities, comes second. This research is about the explicitness of the educational purpose and how that influences the way the game is played and the comprehension of the educational content. Should the game communicate its educational goals beforehand and aid the player along the way, or should we *let the game do the talking*?

This chapter offers a theoretical framework for the development and evaluation of an educational game about overfishing, of which two versions with different levels of explicitness have been developed. This chapter starts with a definition of what exactly a game is, followed by a deeper look in the different types of educational games and in what way these games differ. Then, some important learning theories are discussed. After that, we look at how learning is integrated into the game mechanics of educational games. Next, the influence of explicitness on the game behavior and comprehension in such a game is discussed, leading to the hypotheses which lay the fundaments for the rest of this research.

1.1 Defining the game

Before educational games will be discussed in more detail, it is important to know what exactly defines a game and what makes a game an educational game. Especially interesting in the current context is what distinguishes a game from simulations and educational software (such as interactive education books). A good starting point to get to this difference is the formal definition of a game made by Jesper Juul (2003, as cited in [Ege07, p14]), which defines a game as follows:

> *"A game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome and the consequences of the activity are optional and negotiable."*

As this definition shows, interaction is a defining aspect of a game, because the player can influence the outcome by making a certain effort. Salen and Zimmerman [SZ03, p60] distinguish four modes of interactivity, of which one is the type of interactivity we normally associate with games when we call them an 'interactive medium' (as opposed to films, books and television). This *explicit interactivity* is described as "participation with designed choices and principles." The other modes of interaction can also be applicable to other media, such as a book interacting with one's emotions or a film being discussed by its viewers afterwards.

But this explicit interactivity does not yet differentiate a game from a simulation. Where the real difference lies, according to Juul's definition, is that the player of a game is *attached* to the outcome of the interaction. The game sets certain goals for the player which he has and wants to achieve, as opposed to a simulation or educational software, where the goals (learning how to control an airplane, for example) lay outside the application itself. Users of simulations are nonetheless capable of setting goals for themselves, the so called implicit goals, whereas the goals set by a game are explicit[4] [SZ03].

Egenfeldt-Nielsen [Ege07] suggests that the aspect of artificial conflict should be added to Juul's definition, in order to make a clearer difference between games on the one hand and simulations and educational software on the other hand. This conflict arises as the players struggle towards achieving the game's goals, which are usually difficult to achieve [SZ03]. "Balancing this conflict to best challenge the player is one of the trademarks of a good computer game. When this element is missing, we have a simulation", writes Egenfeldt-Nielsen [Ege07, p15]. The game should not only simulate, but make sure the game offers interesting goals regarding this simulation which challenges the player.

This challenge is generally regarded as one of the main motivations to play games. Crawford [Cra84] suggested that challenge comes from the player continuously willing to learn and improve himself in playing the game. When the challenge is too big (the player does not learn how to improve himself further) or too small (it takes no effort, no new learning to proceed in the game) the player is more likely to give up on the game. This right level of challenge is also the first component of Csikszentmihalyi's flow theory [Csi90], which says that in order to come in a flow, we have to 'confront tasks we have a chance of completing'. To get an optimal flow experience, such a task should require skill and attention and should not be too difficult or too easy. When the task itself becomes the goal and not the experience towards it, it loses the fun factor[5]. This is in line with Crawford [Cra84]: as long as there is something to learn and improve, the game stays interesting and players are motivated to engage in it.

Games are also characterized by their fictional world, with offers context to the rule-based system that defines the game. Such a fictional world can be anything from a medieval fantasy universe to World War II [Ege07, p113]. A fictional world which matches with the rules of the game also gives the players a head start, because they already have knowledge of the elements in the world and how they are supposed to behave. This is the reason many fantasy worlds rely on the same type of creatures and elements over and over again, even though they could come up with entirely different creatures just as easy [Ege07, p113]. An interesting fictional world can also increase player curiosity, which is another motivational factor to play games [Ege07, p59]. But there are also games without a

[4] Later in this thesis explicit and implicit educational games will be discussed, but this is something different than the explicit and implicit goals which are discussed here. These goals merely differentiate a game from a simulation, but have nothing to do with the educational purpose of the game.

[5] Whether this holds true in today's gaming landscape is open for debate, as popular social games such as FarmVille (Zynga, 2009) and CityVille (Zynga, 2010) use goals and achievements to motivate players, offering a fairly dull and time-consuming game experience in between. The fact there is always a goal just within reach keeps people playing.

fictional world, such as Tetris[6] and Pong[7]. These games often have more simple mechanics which are entirely visually represented (there are no invisible variables of relevance in those games).

A game can be called educational if the things learned in the game, whether it are cause and effect relations, concrete facts or abstract concepts, are applicable or relevant outside the game itself and not just help improve playing the game. For many subject matters, this requires the game to have a fictional world which has a close connection with real world concepts. For example, an accurate World War II game might learn players about where and when certain battles took place and what type of machinery was used in that battle. The city building game *SimCity*[8] can learn players that placing a coal plant has a bad influence on its direct environment. The fictional world provides the link between the in game activity and the actual world.

A fictional world is not needed when the educational game learns things which are in themselves abstract, such as math, geometry or reflexes. Tetris can improve the players ability to mentally rotate objects in order to fit them in the grid and a first-person shooter can improve the players reflexes and a puzzle game can improve the player's ability of abstract thinking. These skills are not mechanics from the real world communicated through the game mechanics, but they are skills needed in order to be successful at playing the game.

1.2 Categorization of Educational Games

There are many different types of educational games. Some educational games integrate the educational content in the game mechanics themselves, while other games use classic game formulas and add the educational content on top of that. In his book Educational Potential of Videogames [Ege07], Simon Egenfeldt-Nielsen makes a distinction between three types of educational games: edutainment, commercial games used for education and research-based educational computer games [Ege07, p2,19]. These will be discussed in this section.

1.2.1 Edutainment

Edutainment is a name used for commercially developed educational games, which often use cartoon-like animations and simple gameplay mechanics along with quite traditional educational exercises such as math or spelling. This type of educational games emerged in the late 1980s and became dominant during the 90s, pushing other types of educational computer games out of the market [Ege07, p33]. Some well known edutainment games are the *Pajama Sam* and *Freddi Fish* game series[9]. Educational games are often purchased by and aimed at parents who want to buy games for their children which are more than merely entertainment.

In his book, Egenfeldt-Nielsen is strongly opposed to edutainment games and even refers to them as 'the villain'. "Edutainment [games] are characterized by their use of quite conventional learning theories that rely on training more than learning. They rely on simple gameplay and are mostly

[6] Alexey Pajitnov, 1984
[7] Atari, 1972
[8] Maxis, 1989
[9] Both from Humongous Entertainment, 1994-2004

produced with strict reference to a curriculum. […] Some even question whether they qualify as games." [Ege07, p2] Egenfeldt-Nielsen names edutainment as one of the reasons why educational games did not have the same growth during the nineties as entertainment video games. Scientific criticism on edutainment eventually reached consumers, resulting in a stagnating market [Ege07, p33].

1.2.2 Commercial games used for education

The second type of educational games are commercial games used for education, which include games such as *Sim City, Europa Universalis*[10] and *Civilization*[11]*.* These games are meant first and foremost to be entertaining, but many players do gather new insights about their subject matter along the way. There also have been experiments by using such games in classrooms [Shr05]. These commercial games use a fictional world with many concrete facts which relate to actual history or society, making it possible for players to apply their knowledge gathered from the game in a broader context. The representations used in these games differ from reality in order to facilitate the game mechanics or because of a lack of knowledge on the subject matter by the designers. This could cause the games to teach it's subject the wrong way [Ege07, p188].

Egenfeldt-Nielsen calls the strong motivational factor the strength of these commercial games, because "they feel and play like a 'real' computer game". Still, the application of such games in a strict educational environment is open for discussion. Experiments have shown that commercial games can make students eager about the subject matter and can teach them about the underlying principles of the subject, but they do not transfer much concrete knowledge [Shr05]. They nonetheless offer a framework of concrete experiences which can be a basis for further education.

1.2.3 Research-based educational games

The last category Egenfeldt-Nielsen distinguishes are the research-based educational computer games. The research-based educational computer games are developed taking inspiration from research done in the field of educational games. They have strong documentation for their learning outcomes and try new ways to use the medium of games for learning purposes. But because they are developed in a scientific context, these games often lack the production values associated with the bigger commercial releases [Ege07, p2].

This category includes the earliest educational games such as *The Oregon Trail*[12], which was developed in 1971 by the Minnesota based research center MECC, though it lasted until 1979 when a graphically more advanced version of the game was also available for the general public [Cov07]. In the early 1980s this type of educational games flourished and they were even adopted by commercial game companies, but the rise of edutainment pushed these games out of the market and back in the hands of the scientists.

[10] Paradox Interactive, 2000
[11] MicroProse, 1990
[12] MECC, Minnesota Educational Computing Corporation, 1979

1.3 Dimensions of educational games

The categorization of educational games by Egenfeldt-Nielsen in paragraph 1.2 suggests that the origin of the educational game defines more or less to what category it belongs, but the real differences lie on a more fundamental level. For this thesis we will focus on two dimensions in which educational games differ. The first dimension is related to the way the educational content is integrated in the game, the second dimension to the way the game presents its educational purpose.

In paragraphs 1.3.1 and 1.3.2, these two dimensions will be discussed in more detail. In paragraph 1.3.3 they will be combined into a model which shows how the categories by Egenfeldt-Nielsen are related to the dimensions.

1.3.1 Integration of learning content

The first dimension is the way the learning content is integrated into the game mechanics, or whether or not the learning content is part of the rule-based system that defines the game (see paragraph 1.1). The distinction is made between two categories, the exogenous and endogenous educational games [Hal05].

Exogenous educational games are games where the educational content lies outside ('exo-' means 'outside' in Latin) the game mechanics. According to Halverson [Hal05], these are games where "the learning environment bears no necessary relation to the [educational] content". This translates to games with quiz-like exercises in between or to action games which are interrupted by educational texts. Exogenous educational games are popular in class rooms because these games can easily be fit in the school curriculum and are mostly used to test existing knowledge. They merely offer a nice diversion compared to other school activities, but are not all that different in the end.

Endogenous educational games, on the other hand, "integrate relevant practices of the learning environment into the structure of the game" ('endo-' means 'inside' in Latin). The learning content is integrated into the game mechanics and the player will learn the educational content by playing and mastering the game. With endogenous educational games the game itself is used for learning, instead of as a diversion or motivation between the actual learning content. There has been a lot of aversion to include endogenous educational games in the school curriculum because of their unpredictable learning outcomes. According to professional designers of video games, it is best to embed the learning content "deep in the game mechanics and goals", instead of "bolting it on" [IFH10].

Most endogenous educational games use a fictional world to show the relation between the game and the real world. Endogenous educational games simulate real-world situations to teach the player about how things work in the real world. Such a simulation can be as close to reality as possible, which is a necessity for military training games for example, but can also loosely simulate reality to give an idea of how things globally work. This is for example the case in the city building simulation *SimCity* or in the historical strategy series *Civilization*. Sometimes a more simplified simulation can give a better idea of how real world systems work and leaves more room to implement typical game-like reward-systems in order to make the simulation not only instructive but also engaging and challenging.

An endogenous educational game is never completely endogenous, because the fictional world offering the necessary context to the simulation contains an important part of the educational content, such as historical facts or technical terms. For example, the names and looks of historical figures in *Civilization* are not integrated into the game mechanics, but are part of the fictional world in which the game takes place. But in most endogenous educational games, such information is presented at an appropriate time in the game, for example when that historical figure proposes peace to your nation, and not at a completely random moment when the game play is interrupted with a portion of educational content. What happens when you accept the peace proposal is the part of the educational content which is integrated in the game mechanics themselves and therefore endogenous.

1.3.2 Explicitness of purpose

The second dimension is the explicitness of purpose. Where the integration of learning content is all about the game mechanics themselves, the explicitness of purpose is about how the game presents itself to the player. This explicitness is about whether the educational goals of the game are communicated directly to the player or not, and to what extent. To articulate the differences, a distinction between explicit and implicit educational games is made.

Most implicit educational games are not strictly meant to be educational, but still happen to teach players about their subject matter. These are mostly commercial games developed to be entertaining in the first place, such as *Sim City, Civilization* and *Europa Universalis*. But there are also implicit educational games which are meant to be educational, but do not communicate their educational goals in advance, for example because they want players to discover this educational aspect by themselves.

Explicit educational games are mostly games developed specifically for educational purposes. These games make it very clear what they are about to teach, in advance of the game and most of the times also while playing. Such explicit messages can be adapted to the player´s behavior, with the game acting as a virtual teacher for the player. These explicit messages support the learner by offering an explicit link between the game and the basic concepts, facts, rules and principles of the simulated domain of reality [Leu93].

As long as the learning content fits within the fictional world of the game, it is implicit, even though the fictional world can be partly communicated through text. When there are messages or images in the game which make direct reference to a learning activity or real world applications of the knowledge, the game is explicit. Some games are partly explicit and for example offer an encyclopedia showing how historical figures behaved in real history, even though that might not exactly match with what happens in the fictional world of the game.

1.3.3 Dimensions and categorization

The integration of learning content and the explicitness of purpose are two dimensions which are not necessarily correlated to each other. The first dimension is about the game mechanics themselves, while the other is about the presentation of the educational purpose. Even though exogenous educational games are more likely to be explicit, endogenous educational games can easily be explicit as well as implicit.

Both dimensions are put together in a graph which can be seen in Figure 1. An educational game could be positioned in this graph in relation to other games. The educational game types distinguished by Egenfeldt-Nielsen [Ege07] (edutainment, research-based educational games and commercial videogames) can also be positioned in this graph. These categories are shown in Figure 1 as well.

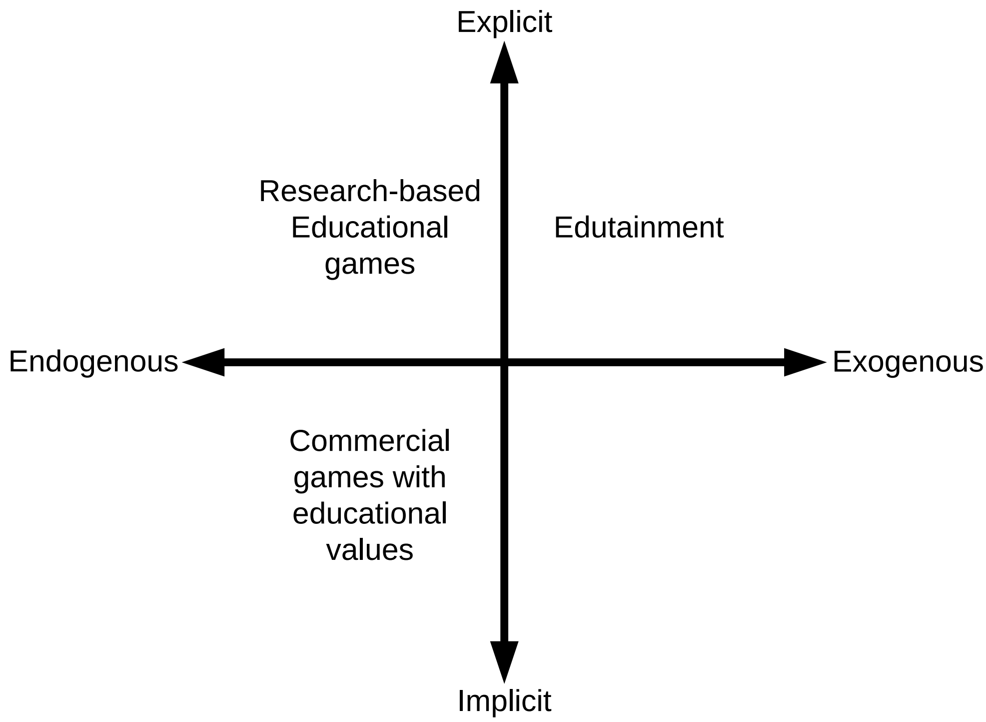

Figure 1: Dimensions of educational games

The categories of Egenfeldt-Nielsen which are shown in Figure 1 will not always match with the appointed area of the graph, but the majority will. Most research based educational games integrate the learning content within the game mechanics, which makes them nearly always endogenous, and they are clearly presented as educational games, which makes them explicit. Edutainment titles are explicit as well, but are mostly exogenous, using drill and practice exercises instead of a more experimental approach to learning. Commercial games with educational properties are not sold as educational games and are therefore implicit. The learning content in these games is nearly always integrated in the game mechanics themselves, which makes them endogenous.

With only the three categories of Egenfeldt-Nielsen, there is one area of Figure 1 which remains empty, being the exogenous implicit games. These are games where the learning content is not integrated in the game mechanics, but which are also not explicitly presented as educational games. Games falling in this category communicate their educational message implicitly through other parts of the game rather than the gameplay, for example in their graphical representation or sound.

An example of such a game is the game *Privates*[13], in which germ-sized soldiers have to fight sexually transmitted diseases. The actual gameplay of this game is just a shooter, but because certain weapons (antibiotics) work well against certain enemies (bacteria), people will learn about the right remedies for sexually transmitted diseases while playing. Other, more subtle approaches in educationally themed games would be to change the graphics in an environmentally aware game when the player's behavior is bad for the environment, even though he might not get punished by the game mechanics itself. The graphics then implicitly hope to convey that the current game behavior is wrong.

Another type of educational game falling in this category is Alert Hockey [CDG08], a research-based game which implicitly alters the game conditions as players show aggressive behavior in a game of ice hockey. Alert Hockey is not endogenous, because the altered game conditions have no connection with reality, but merely with the message the game wants to convey: playing aggressive is not the way to go. Research showed that players changed their game behavior and played less aggressive, even though they were not aware that the game conditions changed. Players then have to reflect on their own play style in order to draw conclusions.

1.4 Learning theories

There are many different theories about how people acquire knowledge. These learning theories do not necessarily exclude each other, but can co-exist in different learning environments. Leonard [Leo02] made a broad categorization of different learning theory paradigms which lead to five categories: behaviorism, cognitivism, constructivism, humanism and organizational learning. From the perspective of educational games, the focus will be on behaviorism on the one hand and constructivism and related theories such as experimentalism and constructionism on the other hand. These two categories more or less overlap with the two types of educational games previously distinguished in paragraph 1.3.1, namely the exogenous and endogenous educational games.

Behaviorists are primarily interested in the behavior learners exhibit and not in why they exhibit that behavior [Jon91]. What happens in the mind is not considered interesting, they only look at the outcomes. The desired behavior of the learner is established through repetition and by rewarding right behavior. Evaluation of behavioristic learning is always based on a certain goal behavior which has to be achieved [BM03]. An educational game developed from a behaviorist's point of view contains clear examples of exercises which need to be reproduced. When a certain number of exercises is done right, the learning objective has been reached. Most educational games which are developed from a behavioristic vision are exogenous educational games such as edutainment. In

[13] Zombie Cow, 2010

such games, the game itself is merely a distraction from classical learning methodologies which rely on repetition of similar exercises.

Constructivism on the other hand, sees learning primarily as a mental process. In constructivism, each learner constructs its own interpretation of reality based on prior experiences, mental structures and beliefs [Jon91]. As opposed to behaviorism, there is no predefined learning outcome. What is learned is different for each learner. This is a disadvantage of constructivism when it is used for training, because it is not clear if the desired outcomes will be reached. For example for the training of an air traffic controller, it is important that all learners have similar learning outcomes [Jon91].

The constructivist view on learning has been used as a basis for other theories which advocate a 'learning by doing' approach as opposed to instructions and explanations. Experiential learning, as formalized by Kolb [Kol84], and constructionism are two well-known examples of those. The latter, introduced by Seymour Papert [Pap91], expands upon constructivism by adding the idea of 'learning by making'. Children do not merely play with their environment, but learn by making things themselves. The most illustrative example is Logo, a simple programming language which allowed children to develop their own (educational) games. Even though constructionism is often associated with learning through games, the learning which takes place when playing an endogenous educational game is closer to experiential learning as defined by Kolb [Kol84], which will be discussed more elaborately in paragraph 1.5.

1.5 Learning and gaming

This section shows how the experiential learning theory applies to endogenous educational games and how the learning content is integrated into the simulation and game mechanics. The learning in games takes place when interacting with the simulation through the game mechanics. This process taking place with this kind of 'learning by experiencing' was formalized by David Kolb [Kol84] as experiential learning.

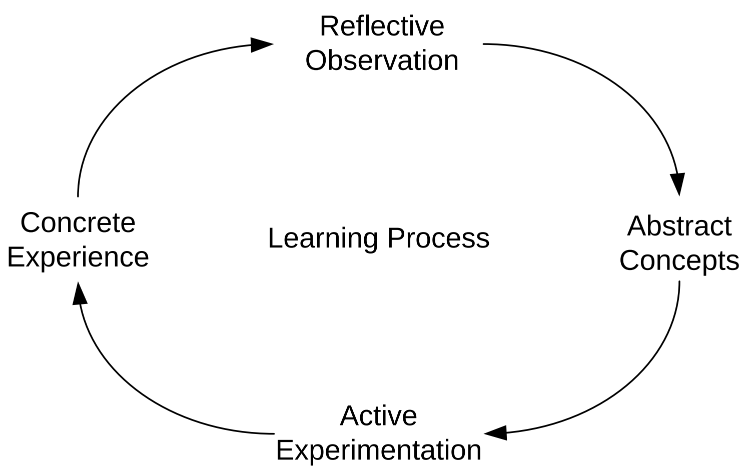

Figure 2: Learning process in experiential learning [Kol84]

Kolb built upon the constructivism theory of Jean Piaget by introducing the concept of experiential learning: learning by making meaning of a direct experience. Kolb sees learning as a circular process, where people continuously update the ideas in their minds by what they experience. Based on their ideas (abstract concepts), people make a decision what to do next (active experimentation) and the outcome of that decision (concrete experience) is interpreted (reflective observation) and can alter the ideas people have, leading to new decisions, and so forth. This circular learning process is illustrated in Figure 2.

When interacting with a game, this cycle is continuously repeated. The abstract concepts influence how the player interacts with the game (experiment), but the game (the experience) then influences the abstract concepts the player has (after reflective observation). This is not only done by the simulation and game mechanics, but also by the fictional world. When the same simulation is used with an entirely different fictional world, this might lead to entirely different ideas about what works and what not, about what is good and what is bad.

The process of playing a game can also be seen as a circular process on a more concrete level [Fab00], which is illustrated in Figure 3 and shows how the player interacts with a game, as opposed to how the game interacts with the mind of the player. There are much similarities with the circular process of experiential learning. Playing a game is a continuous interaction between the player doing actions and the game world reacting. The player then gathers information about the state of the world, analyzes that information and comes to a new decision, which he then performs, altering the game world again.

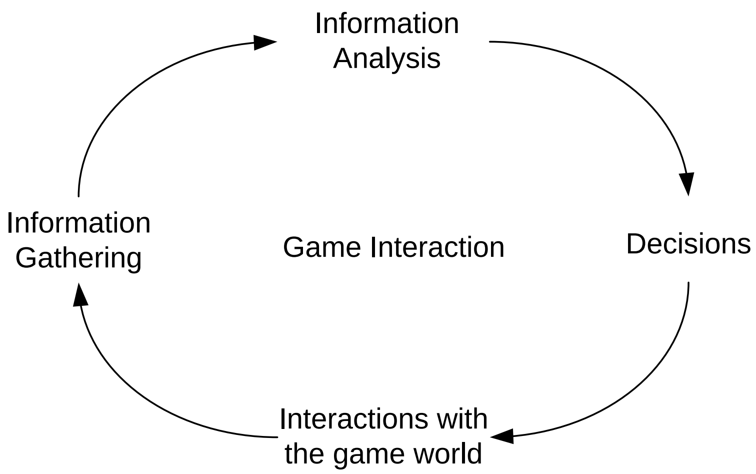

Figure 3: Game interaction cycle [Fab00]

While playing a game, the cycles of Figure 2 and Figure 3 move alongside each other, though they operate on a different level. Figure 3 shows what happens in the game, while Figure 2 shows what happens in the mind of the player. Both cycles are not merely happening at the same time, but are connected with each other. As noted earlier, when playing a game, the player continuously learns how to improve his skills in order to proceed to reach the goals set by the game [Cra84]. The challenge games have to offer, be it beating enemies or solving puzzles, is a learning process. Every time the player dies, he learns something new and updates his abstract concepts of the game. These abstract concepts lead to concrete decisions for what he is about to do in the game world. You could say that making a decision follows on the building of an abstract concept.

In order to use the *medium* games as a learning instrument, as is the case with endogenous educational games, a significant part of the educational content should be part of the learning cycle and gaming cycle. This means that the learning content should be part of the same abstract concepts needed for playing the game. The game's goals can only be reached after the educational content has been understood. The educational content should not interrupt the flow of the game, as text, audio or video for example. For information that is embedded in the fictional world of the game, this means that it should be given at appropriate times, namely when interacting with those elements of the game world in the simulation.

There are different levels of understanding, which can be categorized according to Bloom's Taxonomy of the Cognitive Domain [Blo56, Hui09]. The distinguished levels in Bloom's Taxonomy are knowledge, comprehension, application, analysis, synthesis and evaluation. These levels go from shallow knowledge (reproduction facts, ideas) to deep knowledge (being able to critique on what is learnt). In the game interaction cycle (Figure 3), the first three levels of Bloom's Taxonomy can be recognized. The player gathers low level concepts from the game (knowledge), analyzes this information to build an abstract concept (comprehension) and then applies the knowledge to the game world (application). The formal descriptions of these three levels can be seen in Table 1. When a player knows how to apply the knowledge in the game and can not only reproduce the facts, then he has the deepest comprehension about the game.

Table 1: Bloom's Taxonomy of the Cognitive Domain [Blo56, Hui09] (first three levels)

Level	Definition
Knowledge	Student recalls or recognizes information, ideas, and principles in the approximate form in which they were learned.
Comprehension	Student translates, comprehends, or interprets information based on prior learning.
Application	Student selects, transfers, and uses data and principles to complete a problem or task with a minimum of direction.

1.6 Influence of explicitness

When the educational content is integrated into the learning and the gaming cycle (see Figure 2 and Figure 3), adding an extra layer of explicitness to the game can influence this learning process. By stating a clear educational goal and adding explicit educational messages to the game, the abstract concepts the player has about the game world are influenced. Not by the experiences with the game itself, but by the content of the explicit messages and purpose. This can influence the way the player plays the game.

An explicit educational purpose can directly influence the abstract concepts which would normally have been constructed by the player themselves through experimentation. And as Kolb [Kol84] suggested, different abstract concepts lead to a different active experimentation (see Figure 2), or in the gaming cycle (see Figure 3), to a different decision in the game world. In other words: the explicit purpose changes the way the players play the game: their game behavior.

Leutner [Leu93] found out that adding explicit messages in the form of pre-game tutorials and adaptive guidance significantly improves the game-exceeding knowledge players have about the subject domain (the domain knowledge). At the same time, those players gathered less knowledge about how the game itself worked (functional knowledge). What Leutner did not look at, was how these different forms of guidance changed the actual game behavior. Although the domain knowledge improved, the question remains if that was the accomplishment of the game, or if it were merely the texts in the game explaining the purpose of the game mechanics.

Whether explicit guidance is desirable depends on the educational goals of the game. According to Clarkson and Brook [CB07] the lack of explicit purpose could undermine the value of a game when intended as a learning tool. From an educational point of view, having a clearly defined purpose for an educational activity is more or less the standard. But at the same time, Clarkson and Brook acknowledge that not every game works when having an explicit educational purpose. They see this more or less as an insurmountable problem, deeming such games unsuitable for classroom learning, where 'up front honesty' of educational activities is expected.

Some games might even use the explicit purpose to move the player in a certain direction. Also when the game wants to teach concrete facts and verbal knowledge and not merely abstract simulated concepts, adding explicit messages seems to be an appropriate choice [Leu93]. Egenfeldt-Nielsen [Ege07] confirms this as well, saying that "if reflections are to have an impact outside the game universe, we need quite explicitly to identify these links and lead students in that direction". He compares it with a game of soccer, where physics, anatomy and social relations play a role, and when playing soccer players will experience all of those, but none of them will really be learnt [Ege07].

While the explicit educational messages might aid learning, they can also influence the game behavior of a player. By making the educational goals explicit, the player might be more inclined to play the game conforming the educational goals. They will show less explorative game behavior. When a game is about learning how to drive, the player will more likely abide the traffic rules, than when the game does not explicitly mention that educational goal. When the educational goal is implicit, the player will probably experimentally find out what goes wrong when he does not abide the rules (crash his car, kill pedestrians) and then alter his game behavior (as long as the game's goals can only be met if he does so).

In other words: by adding an explicit educational message, certain possibilities of the simulation are expected to remain unseen. Players might know more and perform better, but might not acquire knowledge about what happens in a 'wrong' situation. And the part they did learn, they might not have learned from the actual game itself but through the messages.

This thesis tries to find out how such an explicit purpose influences how players play the game and what parts of the simulation will they experience. But we also look at how that game behavior impacts the comprehension and perceived fun of the game. Players who did not explore all possibilities of the simulation, are less likely to have knowledge about those aspects of the simulation. They might know how to succeed in the game, but not what happens when things go wrong. In other words, they lack deep knowledge about the simulation. At the same time, the explicitness is expected to make it easier for players to identify what is happening in the game, giving the players more shallow knowledge about the game.

1.7 Fun and challenge

Flow is a state of consciousness where the "concentration so focused that it amounts to absolute absorption in an activity" [Csi90]. When someone is in a flow, they often report great enjoyment of an experience. Chen [Che07] adapted the requirements for a flow experience to computer games, and stated that games should offer a well balanced challenge, clear goals and the feeling of being in control in order for the player to become in the right flow. When the game is not challenging enough players become bored, when the game is too difficult or there are too many choices at hand, they become anxious. Chen pleads that games should adapt themselves or offer multiple choices in order to be attractive for a large group of different gamers.

The importance of a good flow is no different for endogenous educational games[14]. Fu, Su en Yu [FSY09] developed the EGameFlow, a scale to measure enjoyment in an e-learning activity such as educational games. The main difference between flow in educational games and in normal games, is the role of knowledge acquisition in the flow experience. They state that e-learning games become more fun as players increase their knowledge. Also, the knowledge taught has to be applicable in the game itself.

For an endogenous educational game to be fun, this means that the knowledge should be acquired at the pace of the individual player and should build upon previously gathered knowledge. Explicit educational messages can convey knowledge which is yet too far out of reach for the player, building knowledge which the player can not relate to and apply in the game. Also, the explicit educational messages can alter game behavior in such a way that the application of certain knowledge is not required, making the game less fun.

The goals related to the simulation should be achievable with the knowledge the players have about the simulation at that moment or with knowledge that is not too far out of reach. When players get in a certain state where they do not have enough knowledge about the simulation to get to another state, they are stuck in the simulation and are out of the flow. This would make such players perceive

[14] In exogenous educational games, the flow of the game and the flow of the educational content are not related to each other. The flow of the game gets interrupted with an entirely different task which requires a different set of skills.

the game as less fun. It is important that players have gathered enough information about the workings of the simulation before they get in such a situation. Especially without an explicit purpose, it is possible for players to come in such a situation from which they are unable to recover because they did not gather the knowledge needed from the simulation to proceed.

1.8 Hypotheses

Adding an explicit purpose to an endogenous educational game is expected to change the way the game is played, because an explicit purpose changes the abstract concepts the player has about the game [Kol84]. When the game behavior changes, the player will see different parts of the simulation which influences the comprehension of the game's educational content and the player's perceived fun and challenge. The theories discussed in this chapter lead to the following hypotheses:

H1: By adding an explicit purpose to an endogenous educational game, players are likely to show less explorative game behavior than without an explicit purpose.

H2: Players who show more explorative game behavior, will show better deep comprehension of the simulation than people who showed less explorative game behavior.

H3: Players who have showed more explorative game behavior, will have perceived the game as more fun and more challenging than the players who did not.

H4: Players who played an endogenous educational game with an explicit purpose, will have more shallow knowledge related to the game than players who played the same game without an explicit purpose.

Figure 4 shows a broad schematic representation of these hypotheses, with each arrow representing an influence corresponding with a hypothesis. The hypotheses will be concretized in section 4.3, after the game design and methodology have been discussed.

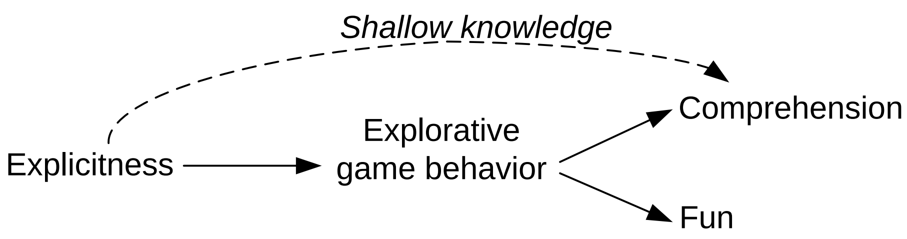

Figure 4: Influence of explicitness on game behavior, comprehension and fun

To discover how the explicitness influences the game behavior and indirectly the comprehension of the educational content, an endogenous educational game which teaches the players about overfishing was developed and evaluated. Two different versions of the game were tested on children, one with explicit messages and presented as an educational game, and one without those aspects.

In Chapter 2 the game design of the developed educational game is discussed. This chapter also shows how the educational content is integrated into the game mechanics. Chapter 3 is about the technical implementation of the game. Chapter 4 discusses the methodology used to evaluate the two different versions of the game and also shows in what way the explicit and implicit version of the game differ. The results of the tests done with the game can be found in Chapter 5. Chapter 6 discusses these results and does some suggestions for future research about this subject.

2 Game design

This chapter discusses the design of the game developed for this research and explains why certain design choices have been made. The name of the game is Vis B.V. (meaning ‘Fish Inc.’) and the educational goal of the game is to teach players the basic mechanics behind the issue of overfishing. A screenshot of the final version of the game can be seen in Figure 5. This should give a global idea of what the game looks like, which might make it easier to interpret the different aspects of the design which will be discussed in this chapter.

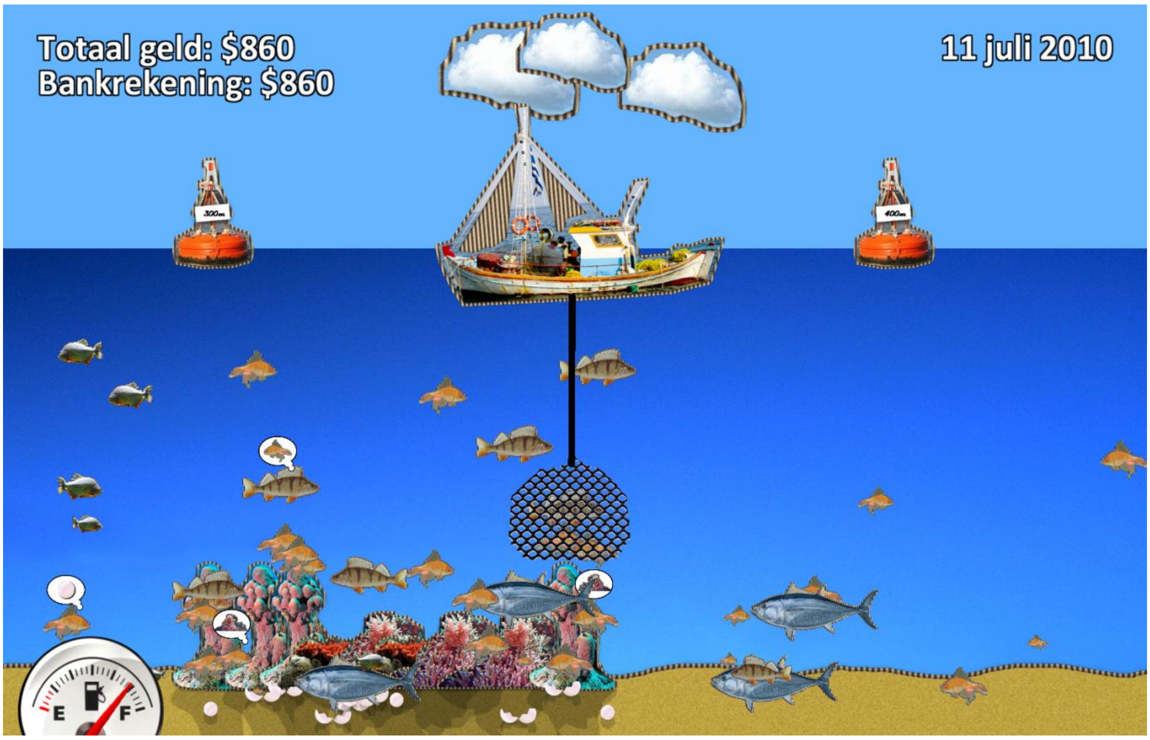

Figure 5: Screenshot from the final version of Vis B.V.

The game described in this chapter is the implicit version of the game, or more appropriate: the basic version of the game. The explicit version has everything that is included in the implicit version, but adds an extra layer of explicitness on top of it. The differences between the two versions are discussed in section 4.1. Everything in this chapter applies to the implicit as well as the explicit version.

2.1 Basic Concept

The player is in charge of a fishing company and has to be the best company by the year 2030 (starting in 2010), which is determined by which company gathered the highest amount of money by that time. The player controls the boat himself and can earn money only by fishing. The fish stock in the game is limited, but fish reproduce over time. Fishing too aggressively will leave the player almost without fish before the end of the game, making it impossible to earn much money anymore.

Fish also need coral reefs and other fish species in order to eat and reproduce and by destroying those, the fish reproduction comes to a halt and fish might die from starvation.

The player should find a good balance in his fishing behavior in order to achieve the maximum amount of money in the end, but this insight requires him to comprehend the workings of the ecosystem by observing what happens in the sea. When the player ends up without fish, he should figure out a way to get his fish stock back to the original level, which is by waiting (or skipping ahead in time) until the fish have had the time to reproduce.

This game design is relatively novel, combining elements of a resource management game with a direct input on the fishing mechanics. Where many games either rely on high-level management or quick reflexes with direct input, this game combines both, urging players to find a balance in how they fish instead of trying to achieve the maximum score as quickly as possible.

2.2 Game design context

Certain aspects have to be taken into account when designing the game. The game does not only need to be fun and be able to communicate the educational content to the player, it also has to be suitable for use in a research context.

To test the influence of explicitness, two versions of the game were devised: an implicit and explicit version. The fact that the game had to be playable with and without explicit guidance is an important factor in the game design. The game has to be playable entirely implicitly, explaining the mechanics of the simulation through interaction, but also should remain challenging and interesting when explicit messages are added.

The experiments lead to a limit for the total duration of the game, which lasted about an hour. Within that timeframe, the players do not only have to play the game, but also get seated, instructed and answer a post-game questionnaire. The actual time left to play the game is about half an hour. Within that small period of time, the players need to learn the game, play the game and experience the simulation enough to gasp the educational content. This means the game should be easy to learn and not overly complex, but interesting enough to maintain attention for at least thirty minutes.

The target age of the game also influenced several design choices. The game was designed for children between 8 and 12 years old. These ages were chosen because the players should at least to be able to read and be able to comprehend a concept such as overfishing. At the same time, the players should not be too aware of the issue of overfishing in advance, which would have been the case with older players.

2.3 Educational content

This section outlines the educational content that is embedded in the game's simulation and fictional world. It is important to define what the exact learning content within the game is, even though it is not the goal of this research to learn things with the game which are actually correct, nor to learn them better than could be done through another medium or classroom education. What is interesting about the educational content is if the content that was intended to be learned from the game, has been learned in the end, and to what degree and in what way.

2.3.1 Subject choice

The theme of sustainability is a hot topic nowadays and it is also a very suitable subject for educational games. Sustainability comes with an interesting balance between short-term profit, long-term investments and limited resources. A small subject within the theme of sustainability was chosen: overfishing. This subject is suitable for real-time simulation, because it is not too broad and the basic concepts behind it should be learned within half an hour. Also, the subject is not part of the standard school curriculum, allowing the game to be tested with children of various ages.

2.3.2 Defining overfishing

Overfishing is defined in the Merriam-Webster[15] dictionary as “to fish to the detriment of (a fishing ground) or to the depletion of (a kind of organism)”. Overfishing does not imply necessarily that fish species have to go instinct, a change in the balance in an ecosystem is also considered as a result of overfishing. Three different types of overfishing are distinguished, being growth overfishing, recruitment overfishing and ecosystem overfishing [Pau83].

Growth overfishing means that young fish (the so called recruits) are caught before they can grow to a reasonable size, having an impact on the future growth of a fish population. With Recruitment overfishing, too much older fish are caught, reducing the number of new fish (the recruits, hence the name) which are produced. Ecosystem overfishing is the most ‘soft concept’, compromising any type of overfishing which changes a mature, efficient ecosystem to an immature and inefficient ecosystem [Pau83]. For example, fish species can increase fast in number because of the decrease in number of their natural enemies or fish species go extinct because the fish species that serve as food are depleted.

Simulation these three type of overfishing properly requires a complex simulated ecosystem, where fish grow to a certain age, have a certain fertile period where they lay or fertilize eggs, and at a certain point die of old age. Also, coping with growth overfishing requires to have nets of various mesh sizes, which lets the smaller fish escape so only the larger fish get caught. Although very interesting for simulation in an overfishing game for older players, within the scope of Vis B.V. the mechanics of overfishing need to be brought back to a couple of basic elements.

The following aspects of overfishing have been chosen to be part of what the game learns to the player:

1) Growth overfishing: Balance between fishing and reproduction.
2) Recruitment overfishing: New born fish do not immediately reproduce, older fish are worth more money (and more attractive to be caught).
3) Ecosystem overfishing:
    a) Larger fish species eat smaller fish species and need the smaller ones to survive.

[15] See www.m-w.com

b) Smaller fish species eat coral and need coral to survive.
c) When larger fish species are depleted, fish stock of smaller fish grows faster.

4) Income vs. fishing: when fish gets depleted, income decreases. Fish needs to be available in order to gather income on the long term.

2.3.3 Learning content in the game

The concept of overfishing will be simulated in a virtual ecosystem and communicated to the player via the interactions he can make with the ecosystem. How this ecosystem works exactly is explained in section 2.5. This section is about how the player will combine simple facts about the ecosystem to a larger comprehension about the entire simulation.

The first three categories of Bloom's taxonomy (seen in Table 1) are applicable to Vis B.V. On the knowledge-level there are simple facts about the simulation which a player can know by just observing what happens in the fictional world of the game. These are facts such as "Fish lay eggs" and "Bombs destroy coral". When the player observes various facts, he can combine them to more complex concepts, which lead to comprehension of the simulation behind the fictional world. The combination of the facts "Larger fish eat smaller fish" and "Fish die when hungry" leads to the conclusion that "Larger fish species need smaller fish to survive". This comprehension of how the simulation works can cause the player to adapt his game behavior, an application of the knowledge. For example, he might decide not to deplete the smaller fish species. An overview of a fair share of the knowledge embedded in Vis B.V. can be seen in Figure 6. This figure shows how the knowledge adds up to comprehension and application using the first three levels of Bloom's Taxonomy.

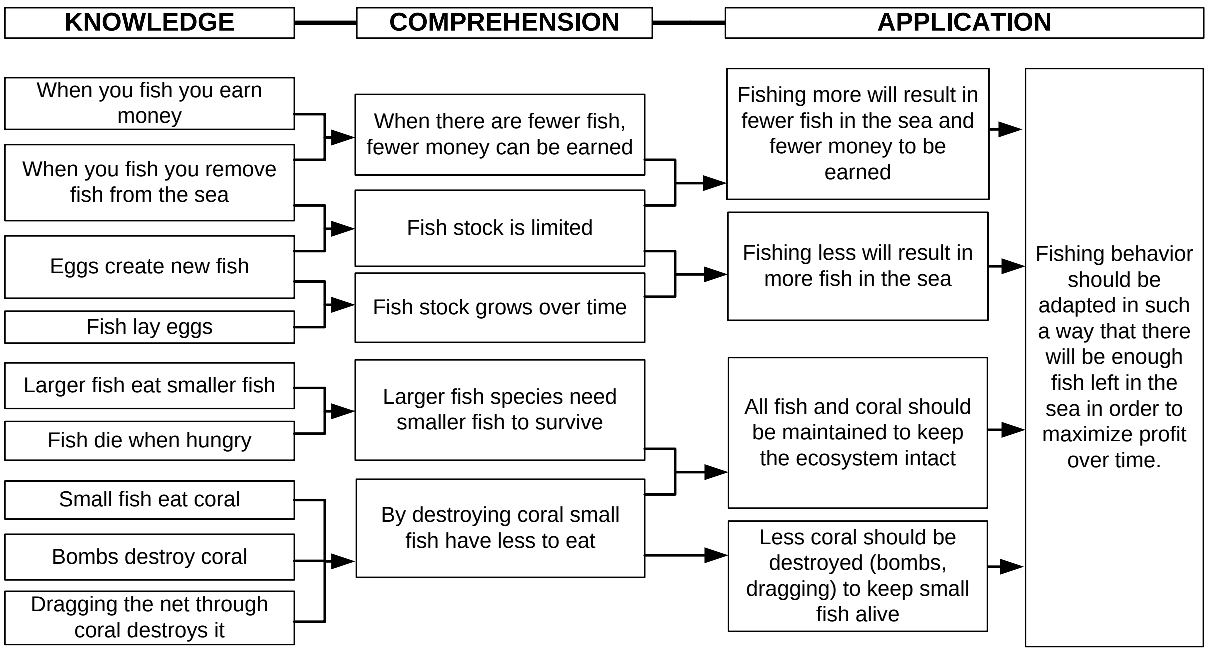

Figure 6: Knowlegde embedded in Vis B.V. categorized using Bloom's Taxonomy [Blo56, Hui09].

There is of course more knowledge in the game than shown in Figure 6. It is also possible that players build their knowledge in an entirely different manner, by combining the facts in a different order or by building upon concepts they already know from previous experiences in their life. There might be players who do not actually witness every event from the first row in Figure 6, but fill in the gaps themselves. Nonetheless, the different levels of comprehension and the concrete examples given will later be used to determine what knowledge has been transferred to the players and how deep they actually comprehended the game. More about that can be read in section 4.2.4.

2.4 Core game mechanics

This section gives a broad overview of how the game works, from starting the game to seeing the game completion screen, which takes roughly thirty minutes. Each separate subsystem is explained in detail in the following sections.

Figure 7 shows a state diagram which gives a broad overview of how the game evolves from the start to the end. In Vis B.V., players catch fish and gain money for every fish they catch. With this money, players can go to the shop and buy upgrades for their boat which allows them to catch fish even quicker. As the player is catching fish, the ecosystem goes on as well. Fish eat and reproduce and as long as the player does not catch more fish than the ecosystem regenerates over time, there will be fish in the sea.

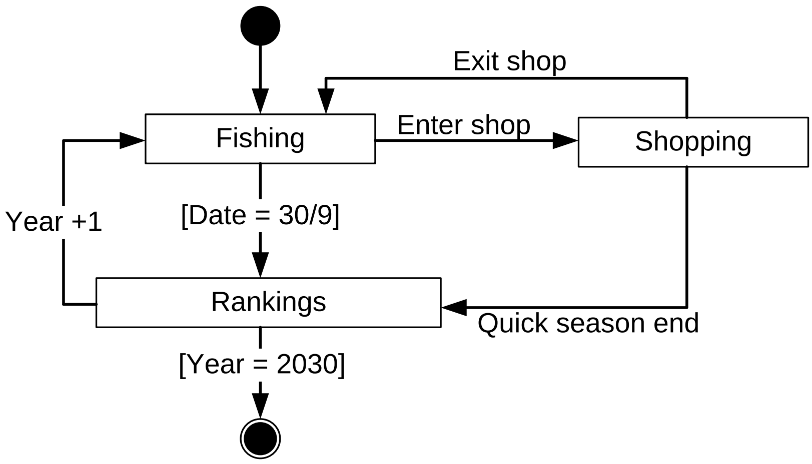

Figure 7: Global state diagram of the game

The game plays out over twenty years, from 2010 to 2030. After each year, the game shows the position of the player compared to the (virtual) competition. This position is based on the total amount of money the player has gathered during the course of the game. The player does not need to wait for the season to end in order to proceed to the next year. In the shop, he can also choose for a 'quick season end', which speeds up the simulation to the next season (the boat will stay on the shore for the rest of the season).

2.5 Ecosystem

The central part of the game is the ecosystem, which is also the part that contains the educational message of the game. While playing, there is a continuously ongoing ecosystem of different fish types which all need food to survive and lay eggs in order to reproduce. All fish lay eggs after a certain amount of time, but newborn fish first need to grow up before they start to lay eggs. Fish also get hungry after some time and will then search for food. When they do not find that food, they will die from starvation after a while. What the different fish species eat is shown in Figure 8. As can be seen in this graph, when the player catches all the smaller fish, the bigger fish will have no food and die as well. When too much coral reefs are destroyed, the smaller fish will be unable to survive. When they go extinct, the big fish will die as well.

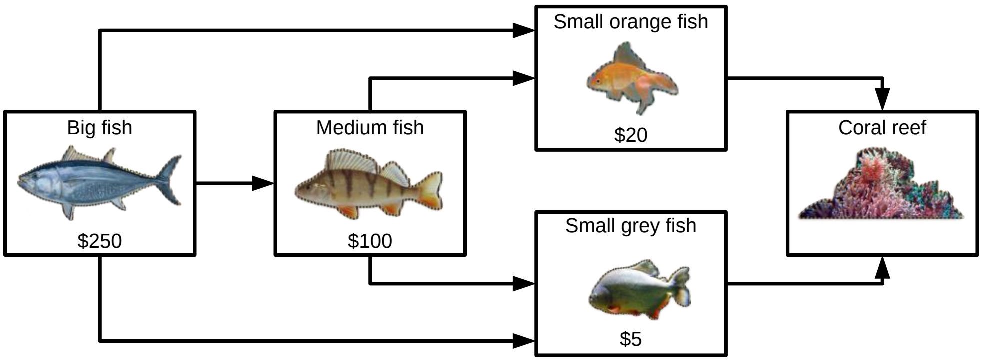

Figure 8: Illustration of the food chain in the game Vis B.V.

The ecosystem is kept simple, with only four different types of fish and coral reefs as the only food in the low end of the food chain. This small size makes the ecosystem easy to comprehend, while still maintaining the idea of a working food chain where certain links can be removed, disrupting the entire chain. There are two smaller fish on the same level of the food chain, one of which is worth more than the other. This allows the more tactical player to choose to catch the more expensive fish, leaving the food chain intact. In order to make it evident to the players what is happening in the ecosystem, the internal goals of the fish are illustrated by icons which are shown above the fish. These icons are shown in Table 2.

Table 2: Icons explaining fish behavior

Icon	Meaning
	The fish is planning to lay an egg
	The fish is hungry and wants to eat from the coral reefs
	The fish is hungry and wants to eat another (smaller) fish
	The fish has died from starvation

2.6 Fishing

In the initial design of the game, many different fishing mechanics were considered, such as harpoons, trawls and rods. But in order to keep the game easy to learn in the short amount of play time, eventually one main fishing method remained: the fish net. This net can be lowered in order to catch fish and can be raised in order to get the fish in the boat and obtain the money the fish are worth. Initially the player only has a small fish net with limited capacity, too small to catch the largest fish type. As the player upgrades the fish net, the size and capacity increase.

There is one other fishing method, being the bomb. The bomb represents the dirty way of fishing: quick, efficient, but damaging to nature. Bombs kill all fish in a large area, which will then float upwards. The player only needs to move over the fish in order to catch them, making it the easiest way to catch a large amount of fish. But the bombs have a disadvantage: they destroy the coral reefs, which the smaller fish need in order to survive. Using much bombs can disrupt the ecosystem, especially when many bombs are dropped in quick succession destroying coral reefs in a larger area.

2.7 Items and upgrades

The player can spend the money he earns by fishing on various items and upgrades for the boat. The players can choose themselves when he wants to upgrade his boat, so they can first take their time to comprehend the basic mechanics of the game. When they have a certain amount of money on the bank, messages will tell the player to buy upgrades in order to make them aware there is a shop. A list of items and upgrades can be seen in Table 3. The items were chosen in such a way that they allowed enough progression, but could all be purchased when playing decently over the course of half an hour. Additional functionality was considered, such as new boats and fishing methods, but those could have made the game too complex to be fully comprehended in the short available play time.

Table 3: Upgrades and items available in the shop

Upgrade/Item	Requirement	Quantity	Description
Bom Bomb	$600	∞	One bomb, used for fishing. Player can have a maximum of 4 bombs. Bombs can be dropped at any time using the space bar.
Volle tank Full tank	$40 per liter	∞	A full tank of fuel, required to move the boat.
5 liter brandstof 5 liters of fuel	$200	∞	5 liters of fuel, required to move the boat.
Groter visnet Larger fishnet	$3000	1	A larger fishnet, increases capacity. Players can catch more fish before they need to raise the net. Allows to catch all types of fish.
Enorm visnet Huge fishnet	$7000 + Groter Visnet	1	An even larger fishnet, with increased capacity.
Gigantisch visnet Gigantic fishnet	$15000 + Enorm Visnet	1	The largest fishnet, with even larger capacity.
Motorblok Vroem Engine Vroem	$2000	1	Faster engine, gives the boat a higher maximum speed.
Motorblok Zoef Engine Zoef	$4000 + Motorblok Vroem	1	Faster engine, gives the boat a higher maximum speed and higher acceleration.

Upgrade/Item	Requirement	Quantity	Description
Gevoelige V-Snaar Engine upgrade	$4000	1	Improves the current engine, increasing acceleration.
Paardenkracht Plus More horsepower	$2000	3	Allows the boat to move while the fishnet is out. The more horsepower, the faster the boat can move while fishing. Dragging the net through coral reefs destroys them.

2.8 Balancing

Balancing the fish reproduction in the ecosystem along with the fishing of the player, is an important aspect of the game. When both are not balanced right, the game will not communicate the educative message. A good balance of the fish stock should abide the following rules:

- When the player does not fish, the fish stock should not grow exponentially. Instead, there should be a natural ceiling in the fish stocks. The total fish stock of a non-fishing player can be seen in Figure 9, stabilizing around 350 fish.
- The player needs some time to see the ecosystem working before the fish stocks decline by his fishing behavior, otherwise he might get stuck in a situation without fish which will disrupt the flow of the game. When the player has not upgraded his boat, he should not be able to deplete his fish stock (see Figure 10, section 1).
- When the player upgrades his boat, it should be quite easy to get in the negative spiral and depleting the fish stock (see Figure 10, section 2).
- When the player stops fishing or skips seasons, the fish stock should restore faster than it declined in the first place (see Figure 10, section 3).
- When players find a good balance in the amount of fish they catch, the number one spot in the rankings should be achieved while the number of fish in the sea stays at a decent level (see Figure 10, section 4).

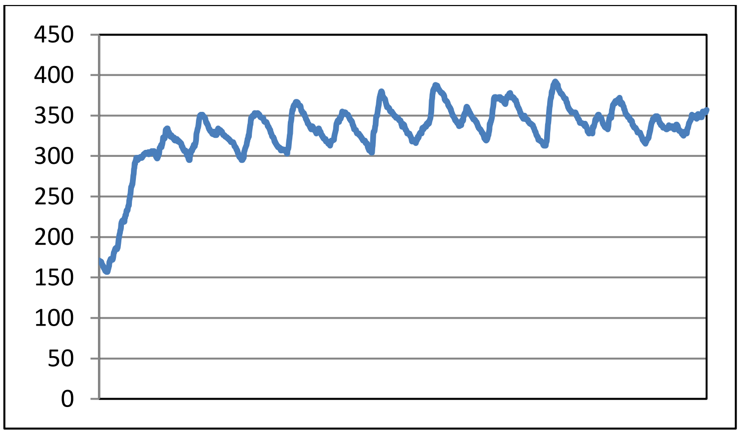

Figure 9: Total fish stock of non-fishing player over time, stabilizes at around 350 fish.

2.1 Goal

The goal of the game as communicated to the player will be to make as much profit as possible over the course of a certain number of years. As should be the case in an endogenous educational game, this goal can only be reached in engaging with the underlying simulation. In the implicit version of the game, it is never communicated that the fish stock is of any importance, but while playing the game and interacting with the fish stock, this should become evident to the player. The way to become most profitable on the long run, will be by not depleting the fish stock.

Because making profit will give the player the ability to buy upgrades for his ship, he will start fishing faster and it will become easier to deplete the fish stock. Spending income does not derive from the goal, because the total income will be the measurement and not the income minus expenses. This was done to make the player not reluctant to spend money in the shop. The total amount of money is used in a similar way as the 'score' in arcade video games and does not decrease by other actions. This means that how the more fish the player catches over time, the more money he has made and the higher his score.

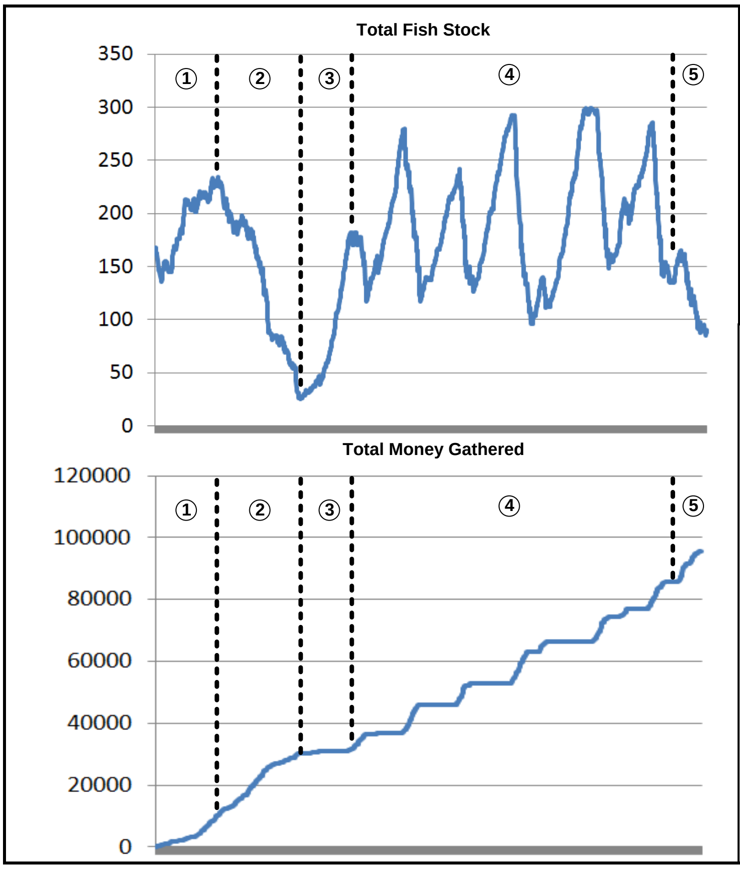

Figure 10: Image showing the fish stock and money over the course of a single game, with five different play styles being adapted:
1) Fishing without upgrades; fish stock grows, money grows slightly
2) Fishing aggressively after buying upgrades; fish stock declines fast, money grows quickly
3) Skipping seasons/slow fishing to make fish stock grow back; fish grows, no money gathered
4) Alternating between fishing and waiting/skipping seasons; fish stock declines slightly and grows back
5) Last year: player decides to fish what is left

2.2 Presentation

The game uses a two-dimensional, sideway view. This gives the player a good view of what happens under sea level, as opposed to a top-down view. A three-dimensional game design was not chosen, because it is easier to get a high level of polish and attractive graphics when using 2D graphics. Figure 11 shows the game screen including a description of several interface elements.

The game world spans several screens which smoothly scroll as the boat moves. The boat can only move from left to right which is done by using the left and right arrow keys. The fishing is done by moving the net up and down with the up and down arrow keys. When the player has bombs, they can be dropped with the spacebar.

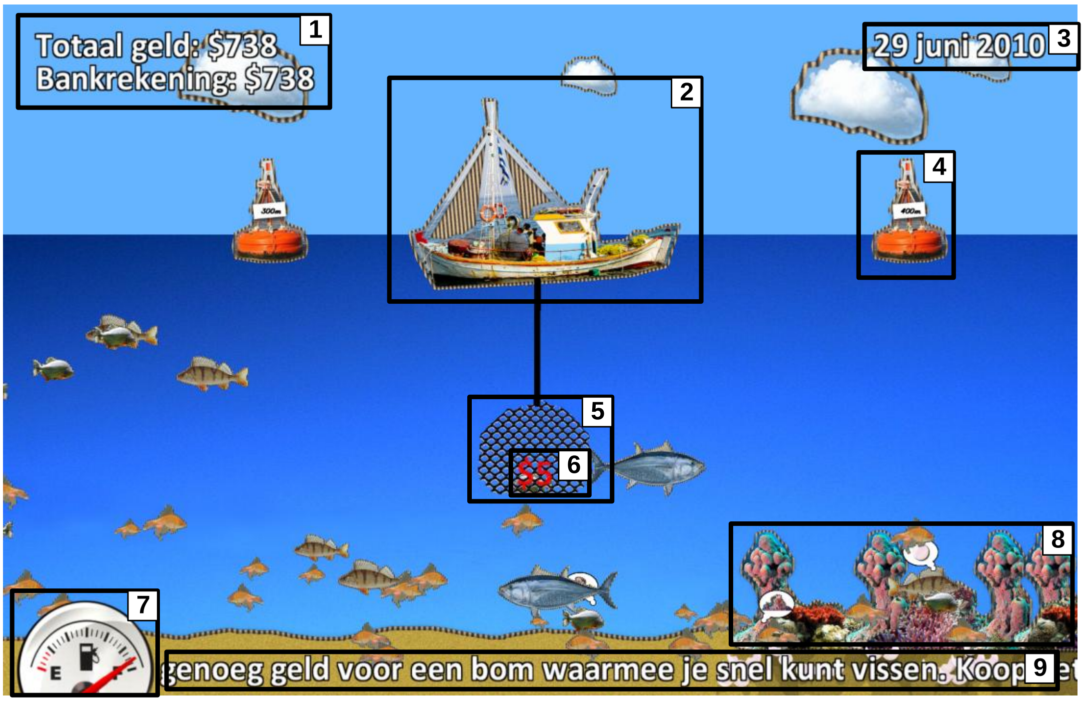

Figure 11: Screenshot of the game with (1) current and total money (2) the player boat (3) the in game date (4) buoys showing distance (5) the fish net (6) a fish getting caught displaying the money the fish is worth (7) the fuel meter (8) coral reefs and (9) the message bar displaying when items are purchasable in the shop.

Figure 12: Screenshot from the shop in Vis B.V.

On the far left end of the world there is a small harbor which serves as the shop. By pressing the 'Enter' key, players can enter the shop and purchase stuff from a simple textual menu (see Figure 12). At the far right end, the world just stops scrolling and a buoy shows the end of the world has been reached.

2.3 Evolving design

The design of Vis B.V. has evolved a lot during the development of the game. Many changes were influenced by having people play the game at different phases during its development. In this section, the changes these sessions led to for the final game design are described.

Children as well as adults were used to test the game during development. These 'pilot tests' confirmed the idea that the game was more suitable for children, as the adult test persons got the educational goals behind the game quite quickly, sometimes even at a glance. Most adults are aware of over fishing and expect such themes in a game developed for scientific purposes.

The pilot tests were used in particular for balancing the game and the ecosystem. For many players, it took too long to empty the sea and too long for the fish to come back when the fish was finally gone. To improve this, the following changes were done:

- Reduced size of the game world
- Increased speed of fish reproduction
- Removed fish gender and egg fertilization
- Quick Season End-option to fast forward the game

When tests were done with children, none of the children really comprehended how the ecosystem worked, which could have been caused by a lack of feedback on the events in the ecosystem. Even simple things such as the eggs which were laid by the fish, were not recognized as eggs by some players. This problems have been addressed by the following changes:

- Added sound effects for the most important ecosystem events (chewing for eating, cracking for eggs breaking open)
- Added small animation of eggs breaking open when fish comes out
- Added cartoon-like icons showing when fish are eaten (with the text 'Hap', which means 'Bite')

Also, some children did not immediately pick up the right controls. They tried to use the mouse instead of the keyboard arrows. This has been addressed by adding a text explaining the keys when the game starts. Also, at the final experiments the mouse was physically put away so children were not able to pick it up.

3 Development and implementation

The game Vis B.V. was developed using the XNA Framework by Microsoft, a C#-extension which offers various tools and interfaces tailored to game development. For example, XNA offers native support for Xbox 360 controllers and can easily render a large number of two-dimensional images to the screen at once. XNA also supports simple graphical effects such as scaling and alpha-blending sprites, which are good tools for making the graphics look more dynamic without the use of animation.

3.1 Graphics

For the graphical style of the game, a short drawing-time was important, but at the same time the game should look attractive. As noted by professional game developers, games from independent game developers often have great, attractive and original visual styles which do not require the time and resources needed seen in most modern three-dimensional games [IFH10].

A similar philosophy was used for the graphical style in Vis B.V, using a cut-out cardboard look, where cutouts from photographic images are pasted upon a cardboard texture. Even though the photographs come from various different sources, due to the cardboard outlining they come together as a coherent image. The cardboard-style also makes it more plausible that fish and other elements lack animation. For creating the graphics, the GNU Image Manipulation Program (GIMP) [Gim10] was used.

Figure 13: Three layers (image, shadow and cardboard) coming together as a cloud.

3.2 Implementation

XNA has a basic structure with two important functions: Update and Draw. Update is called exactly thirty times every second and is used to update the state of the game world, such as the movement and animation of the fish, buoys, clouds as well as the player’s boat. Update also calls the InputProcessor to handle the player input and updates the player’s boat movement parameters accordingly. The Draw-function is called as many times as possible, based on how much computation time is needed for each call, and draws the current state of the game world to the screen.

For Vis B.V. a structure with autonomous objects was chosen, where every single object has its own draw and update function. Each object has its own texture and can draw itself to the screen on a given position. The object also updates itself to a new position, even though other classes can be responsible for setting the parameters for that movement, such as speed, direction or the movement goal. A global overview of how the game is constructed can be seen in the class diagram in Figure 14. Only the most relevant or illustrative classes, functions and relations are shown, otherwise the diagram would get too convoluted.

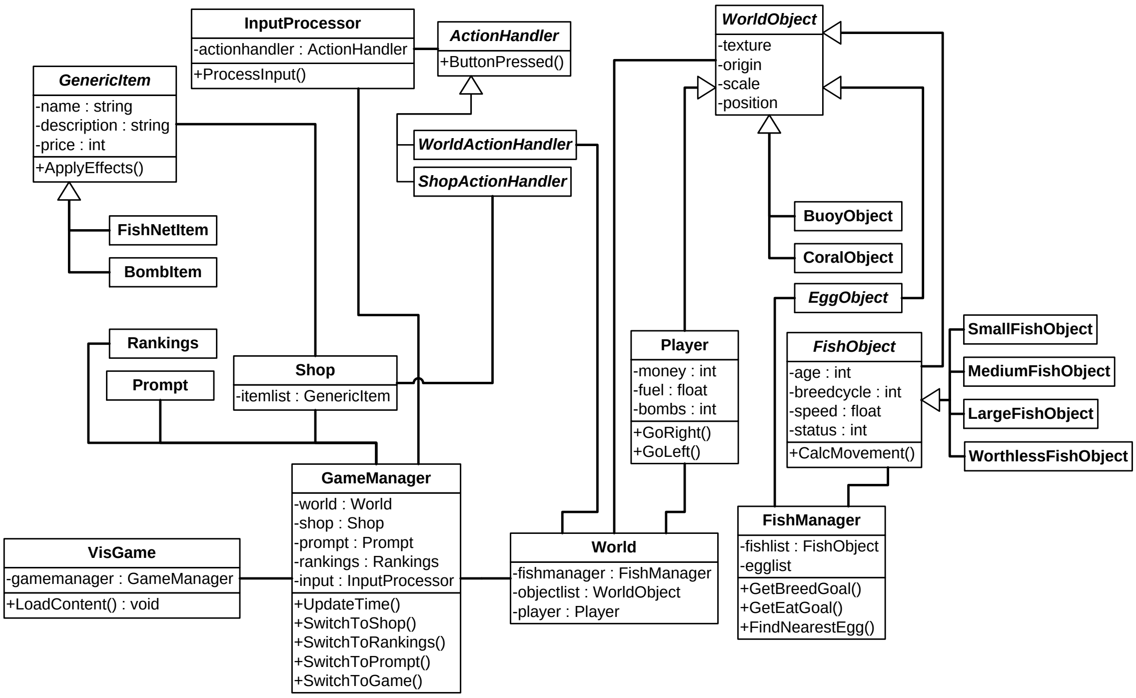

Figure 14: Global Class Diagram of Vis B.V.

The GameManager-class is the central class of the game and is responsible for switching between the title screen, shop, rankings, prompts and actual game. The game world itself is handled in the World-class, which contains a list of the objects in the game (the objectlist). The World-class also contains a FishManager, which has a list with all the fish in the game and is responsible for setting the goals for the fish, hatching the eggs and removing the fish when caught.

When the game world is updated during game play, the update-function of World gets called. World updates all of its own objects, such as the buoys and clouds, and then calls the update function of the FishManager. The FishManager then updates each of the fish, which then autonomously move towards their goals previously set by the fish manager. When the draw function is called, the World-class makes sure only the objects on screen are drawn. To achieve the scrolling effect, the positions are calculated relative to the player's position and all objects falling off the screen are not drawn. When they are drawn as well, this would slow down the game tremendously and make it unplayable.

If the player goes to the shop, the season ends or the game shows a prompt, the GameManager changes the status accordingly. At the same time, a different action handler is assigned, so the keyboard input gets processed to the shop, prompt or rankings instead of to the game world. When the GameManager is not in the 'ingame' status, the World is not updated anymore. This means that the fish and all other objects in the world stop moving. The game world is still drawn and the current activity, being it prompts, the shop or the rankings, are drawn on top of it with a semi-transparent background. By doing this, the game world itself never seems far away from where the player currently is in the game.

Each object in the game world is an extension of the type WorldObject. WorldObject defines the default properties of each object, such as a texture, scale and position in the world. It also contains aid functions such as a request-function for the on screen width of the object, which is needed to calculate whether an object is on the current screen or not. A special type of WorldObject is the FishObject, which is a class that contains everything the different fish have in common. The separate fish classes only overwrite default values such as the breed cycle, size, texture, price and speed of the fish. The Player class is also of the type WorldObject because it has a lot in common with other objects, except the behavior of the object is determined by the player input and not the GameManager of FishManager.

4 Methodology

Two different versions of the game have been tested with a group of children between 8 and 12 years old. The two versions of the game both had exactly the same game mechanics, as described in Chapter 2, but differed in their level of explicitness. All relevant data of the game session was logged in order to characterize game behavior and to find out if there are relations between the explicitness and game behavior and between the game behavior and the comprehension. Comprehension was tested with a post-game comprehension test. A post-game questionnaire was used to gather an overall opinion about the game.

4.1 Different versions

Two different versions of the game were made, an implicit and an explicit version. The implicit version is the basic version: everything that is in the implicit version, is also in the explicit version. The things added for the explicit version are all regarding the textual representation. The game mechanics are exactly the same for both versions. As Leutner [Leu93] suggested, in order to have the greatest influence on the learning results, an explicit educational purpose should be communicated through pre-tutorial texts as well as adaptive advice throughout the game. This lead to the following differences between the implicit and explicit version.

The first difference is the opening text, which children have to read before they start playing the game. The opening text is short, less than 75 words for both versions, and outlines the basic goals of the game so children know what to do when they start playing. The two texts can be seen in Table 4 (translated from Dutch). The implicit text only tells the player to earn money, while the other text explicitly mentions the environmental issues related to fishing. The explicit text does not literally explain the mechanics behind overfishing, in order to still be able to see whether they learned the actual mechanics from the game or not.

Table 4: Difference in opening texts between implicit and explicit version

Implicit	Explicit
From today on, you're the boss of Fish Inc., now only a small fishing company between the big boys. Can you make Fish Inc. the best fishing company? This is the company which earned the most money by the year 2030.	From today on, you're the boss of Fish Inc., a small fishing company that does not join the big boys. Of course it is important to earn money, but not at the cost of the environment. Children in the year 2030 should also be able to eat fish. Make sure enough money is earned, but also make sure that there is fish left in the sea.

Another difference between the implicit and explicit version are the texts which are presented throughout the game. The explicit version will prompt a full screen message (which shortly interrupts the game) depending on the behavior of the player. When the behavior of the player is likely to disrupt the ecosystem, this prompt will give the player a warning pointing out the risks of the current behavior. There are two different prompts in the game. Table 5 shows the situation in which they are shown and the message they show (translated from Dutch).

The messages are formulated in such a way that they do tell the player he should alter his behavior, but not in such a way that they will comprehend why exactly. For example, the message about the coral reefs does not mention that the small fish eat from the coral reef, nor that the bigger fish need to eat the small fish to survive. Instead, it only mentions the eventual consequence, being that the fish might get extinct when too much coral reefs get destroyed. This was done so the deep knowledge (on the application level of Bloom's Taxonomy [Blo56]) was communicated through the game and not the explicit messages themselves. The messages also do not make it mandatory of the player to alter his behavior. He is free to continue the way he was playing, even though this might harm the virtual ecosystem. The messages will show again when the same situation occurs again after recovery, but not when the situation remains the same.

Table 5: Prompts in the explicit version of the game

Situation	Message
Fish stock of a fish species drops below one third of the initial amount of fish.	Watch out! One of the fish species is threatened by extinction. Try not to fish too much of that type of fish. Fish need each other to survive. And when all fish is gone, no money can be earned.
More than five parts (of approximately 25) of coral reef have been destroyed.	Watch out! Do not destroy too many plants. Fish need this to survive. Give plants time to recover. When you destroy too many plants, fish might get extinct.

4.2 Measurements

The game behavior measurements consist of a data log of all relevant in-game actions by the player as well as data from the ecosystem. To measure comprehension and opinion (perceived fun, difficulty, excitement, etc.), a post-game questionnaire and a comprehension test were used.

4.2.1 Game behavior data

During play, a data log is generated tracking all relevant variables during the course of the game. The data is logged with an interval of one second. This allows the data to be plotted over the course of the game and for example to make a visual representation of the growing and declining fish stocks. Along with the data log, an event log is generated with all relevant actions over the course of the game, such as buying stuff or dropping bombs. These actions are tagged with a timestamp so they can be related to the data in the data logs.

The logged data and events can be seen in Table 6. Some data was analyzed using a derivate from the data, such as a minimum, average or maximum. For logged events, the total number of times a certain event has happened was used for further analyzing. These derivatives can be seen in the second column of Table 6.

Table 6: Overview of data logged every second and events logged when occurred.

Data logged	Derivative
Actual number of fish	Average fish
	Minimum number of fish
	Maximum number of fish
Actual number of fish per type	Average fish per type
	Minimum number of fish per type
	Maximum number of fish per type
Total eggs laid	-
Total births	-
Current x-position	Average x-position
Current money	Average money
Total money	-
Current fuel	-
Current bombs	-
Current coral destructed	Average coral destruction
Events logged	**Derivative**
Purchase done	Total purchases
Bomb purchased	Number of bombs purchased
Bomb dropped	Number of bombs dropped
Boat upgrade purchased	Number of boat upgrades
Fuel purchased	Number of fuel purchases
Quick season end	Number of quick season ends
Year end	-
Normal instructive message	-
Explicit message prompt	Number of prompts

4.2.2 Fish stock characterization

As was suggested in the hypotheses in section 1.8, a different level of explicitness in an educational videogame leads to different game behavior of the player. What is mainly interesting is how the game behavior changes in relation to the part of the game where the educational knowledge is embedded: the simulation. In the case of Vis B.V., this simulation is the ecosystem. In order to compare the play behavior of the various players, the fish stock development will be characterized based on the data gathered about the ecosystem from the data logs.

The level of explicitness was predicted to have influence on the aspects of the simulation the player would witness. Therefore, the different characterizations indicate how much the player has seen of the simulation, or how explorative his game behavior was. In the case of Vis B.V., the player has explored most of the simulation when the fish stock got nearly depleted and then restored again to its original level. When that happens, it is called the ‘recovery’ fish stock characteristic. Some players will deplete the fish stock, but will not recover from that situation. This will be called ‘fish to zero’. Players who did not deplete the fish stock at all, exhibit the ‘stable’ fish stock characteristic. The three characterizations along with how they are determined can be seen in Table 7.

Table 7: Fish stock characterizations

Characterization	Description	Measurement	Exploration
Recovery	One or more fish species got (nearly) extinct, but were back to their original population later in the game	Number of fish drops below threshold but is above threshold again later in the game	Much
Fish to zero	One or more fish species got (nearly) extinct	Number of fish drops below extinction threshold of approx. 1/5th of original number	Some
Stable	None of the fish species got (nearly) extinct, the fish stock was more or less stable during the game	None of the fish species drops below the extinction threshold during the entire game	Little

4.2.3 Questionnaire

How much the players liked the game was determined by a questionnaire. This questionnaire was kept short because the comprehension test would already require a lot of time for the children and was considered of more importance. The main goal of the questionnaire is to get an idea whether there are great differences in how children perceived the game for various conditions.

The questionnaire starts with six questions asking about their opinion of various aspects of the game, using a five point Likert rating scale. Research showed that children prefer a five-point scale above putting a mark on an analogue line, preferably a scale where all individual answers are written out [LZD04]. This was not done because this would make the questionnaire seem too long. The questionnaire was part of the pilot test, because especially with children it is hard to predict what they will understand [Opp92]. Pilot tests also showed that children comprehended the rating scales and used it appropriately, but when they first saw the questionnaire some children complained that they had to fill out ‘three whole pages’.

The players are asked how much fun, how exciting, how instructive, how difficult and how beautiful they found the game. Difficulty and excitement should together give an idea of the challenge of the game, as the right difficulty gets players in a flow, which is perceived as exciting [Csi90]. The Dutch word for challenging (*uitdagend*) was considered too difficult to comprehend for the younger children. Also they were asked when during play they found the game the most fun: at the beginning, in the middle, at the end or during the entire play session. This part of the questionnaire is followed by a comprehension test, which will be discussed in section 4.2.4.

After the comprehension test, at the end of the questionnaire, the children are asked for their age, gender and how much they use a computer and play computer games, factors which might have influenced their game behavior. Because the subjects are young children with a short attention span, the questionnaire is kept short and the questions are formulated with easy wordings. The entire questionnaire including the comprehension test can be found in Appendix I.

4.2.4 Comprehension test

The comprehension test is used to determine how well the children comprehended the game. This part is like a typical school test, with questions which have specific right and wrong answers. The questions determine the comprehension of the game on the first three levels of Bloom's Taxonomy of the Cognitive Domain [Blo56], being Knowledge, Comprehension and Application. Due to the young age, short attention span and slow reading of some children, the comprehension test is kept short and easy wordings are used.

The comprehension test starts out with a set of questions which determine whether the children have correctly comprehended the different elements and options in the game. These closed questions are used to test the factual knowledge about the game, the first level of Bloom's Taxonomy. First, there are a couple of true/false questions about the most basic cause and effect relations in the game, such as what happens when a bomb is dropped or whether the big fish eat the small fish in the game. Next, there are five multiple-choice questions which mainly ask what the icons in the game represent (see also Table 2 in section 2.5).

The comprehension test ends with four open questions. Two questions are on the comprehension level of Bloom's Taxonomy: do the players know what happens in the ecosystem? The other two questions are on the application level and ask the player about the best tactics in certain situations. These questions should determine whether a player understood the workings of the ecosystem and if he is able to apply that knowledge in practice. Open questions were chosen because to prevent children from guessing right and to prevent the answers giving children ideas they did not come up with themselves.

The use of a test to determine the success of an educational game has been done before, but mostly with games which educated simple facts or abilities, such as topography or math [CS04]. These researches used a pre- and a post-test in order to determine how much the knowledge or ability has improved while playing the game and they compared that with typical text book exercises. To prevent children from being aware of the goals of the experiment, this approach was not chosen. In order to still get an idea of the influence of prior knowledge, two additional multiple choice questions are used to determine what they know about threatened species and the environment in general. These questions come at the very end of the test, after the open questions.

4.2.5 Comprehension scores

In order to make the comprehension test results easily comparable between subjects, the answers were converted into comprehension scores for each of the three parts of the comprehension test, as well as a cumulative score for the entire test. The scores are calculated as shown in Table 8.

As can be seen in Table 8, each right answer adds one point to the comprehension score. For multiple-choice questions where multiple answers are correct, more than one point can be earned. For every omission or wrong answer 0.5 points get subtracted. This calculation method gives the best comparable scores, even though for some multiple-choice questions a higher total number of points can be earned. For the open questions, points can be earned when respondents used pre-determined relevant terms in their answers. Of course, these terms also have to be used in the right context. The answers to the questions can be seen in Appendix II. The multiple choice questions about the prior knowledge of the children are disregarded in the comprehension scores, because they give no indication of how well the game or the educational content have been comprehended.

Table 8: Calculation of the comprehension scores

Type of question	Score calculation	Total Points
True/False	1 point per correct answer	0 – 6 pt
Multiple choice	1 point per correct answer, -0.5 per incorrect/omission	1 – 10 pt
Open	3 points per answer, based on relevant terms mentioned in the answer (1 pt per term)	1 – 12 pt
Total	T/F + MC + Open	0 – 28 pt

4.3 Hypothesis

The hypotheses from Chapter 1 can now be made more concrete for Vis B.V. in specific. The ‘explorative game behavior’ from the original hypothesis can be determined with the fish stock characteristics, where ‘recovery’ is the most explorative type of game behavior. The deep knowledge is determined with the open questions of the comprehension test, the domain knowledge with the closed questions.

H1: By adding an explicit purpose to Vis B.V., players are less likely to deplete the fish stocks and show the ‘fish to zero’ or ‘recovery’ fish stock characteristic and are also less likely to destroy the coral reefs than players who play the game without an explicit purpose.

H2: Players who show the fish stock characteristic ‘recovery’, will have higher scores on the open questions of the comprehension test than players who show the other fish stock characteristics.

H3: Players who show the fish stock characteristic ‘recovery’, will report a higher perceived fun and excitement on the comprehension test than players who did not.

H4: Players of the explicit version of Vis B.V. are expected to score better on the closed questions than players of the implicit version.

4.4 Procedure

The experiments were done with a maximum of four children at the same time on four separate PCs. The game was controlled by the use of a keyboard. The experiment room had little distractions. The PC's were positioned in such a way that the children could not look at each other's screens when playing. Every PC was equipped with a headphone which was required to hear the sound effects of the game, but also made the children less inclined to talk with each other. Two pictures of the test setup can be seen in Figure 15.

During the experiment, the children got to play either the implicit or the explicit version of the game. The children first got a short explanation of the content and procedure of the experiment. It was emphasized that it was not a competition and they could play at their own pace. They were also told that it was important to read the text in the game and the text on the main screen.

Figure 15: The test setup

After the setup and instructions, the subjects played the game. The time of a play session was for the largest part determined by the game itself, which has a pre-determined game time of about thirty minutes. The player can slightly speed up this play time by using a lot of quick season ends and slightly slow down the play time by spending time in the shop. During the play session, notes were taken when children said something or showed remarkable behavior. When children asked questions, they were told to try to figure things out themselves. When they repeatedly kept asking the same questions and they were not about the essence of the game (i.e. the ecosystem), they were answered by a returning question which could give them a hint to what to do (for example: maybe there is somewhere where you can spend your money?).

After playing the game, the children had to answer the questionnaire and comprehension test. They were told it was not a problem when they answered things wrong. It was pointed out to them that it was the game which was being tested, not themselves, and that it was important to know what they comprehended and what not [HRA97]. When the children asked questions about the questionnaire, they were told just to answer what they thought was the right answer. If they really did not know, they were told to leave that option blank. After they finished the questionnaire, the children were free to play the game again if they wanted to (most of them did) or to have a drink or something to eat.

5 Results

The experiment was done with 13 children (N=13) between the ages 8 and 11 (M=8.69, SD=1,494). 6 of them were girls, 7 of them were boys. Of these children 5 (1 girl, 4 boys) played the explicit version and 8 (5 girls, 3 boys) played the implicit version. Between two and four children were playing the game at the same time in the same room. The age of the players of the implicit version was slightly lower (M=8.50) than the age of the players of the explicit version (M=9.00). Players of the explicit version saw 6,6 explicit messages on average (SD=3,91), including the title screen.

5.1 Explicitness and game behavior

Hypothesis H1 predicted that players of the implicit version would show more explorative game behavior. In section 4.2.2 three types of game behavior regarding the fish stock development were characterized: fish to zero, recovery and stable. These fish stock characteristics are used as an indication of how explorative the game behavior was. For hypothesis H1 this means that players of the implicit version would more likely show the 'fish to zero' or 'recovery' fish stock characteristic, whereas players of the explicit version would be more likely to show 'stable' fish stock characteristics.

Table 9 shows the number of times each of these fish stock characteristics happened for both versions of the game. A chi-square test shows no significant (α=.05) statistic relation between the explicitness and fish stock behavior (χ^2=.352, p=.850). This means hypothesis H1 cannot be confirmed. Using a t-test, the separate variables related to the fish stocks[16] showed no significant differences with explicitness either.

Table 9: Occurrences of the different fish stock characteristics for implicit and explicit

	Implicit	Explicit	Total
Stable	4	2	6
Recovery	2	2	4
Fish to zero	2	1	3

Six players did not drop the fish stock of any of the four fish species below the threshold defined in section 4.2.2 and can be considered 'stable' fishers. It was expected that players who played the explicit version would show the 'stable' fish stock characteristic more than players of the implicit version, but the opposite seemed to happen, even though the differences were not significant.

Of the seven other players who did drop their fish stock below the threshold, four managed to recover and three did not. Of the three who did not recover (the 'fish to zero' group), two dropped

[16] These are variables such as 'the maximum number of fish' and 'the average number of fish'. It is interesting to look at these variables separately, because the fish stock characteristics only look at one aspect of fish stock development, being fish depletion.

below the threshold just before the end of the game. These players did not get the chance to change their tactics and recover the fish stock, so they might have qualified for the ‘recovery’ category when the game went on a little longer. Still, these players did not see the process of recovery in the game. There is only one player who depleted the fish stock quite early on and did not recover at all. This player played the implicit version of the game.

Of the four players who recovered, two only dropped one specie to zero (the largest fish) while the other fish types were more or less stable or showed only a slight decline. The other two players had a large decline of all fish species, with two or three species dropping below the threshold. This happened in the last quarter of the game for both players, who both recovered their fish stock before the game ended. An example of the fish stock development of a recovering player can be seen in Figure 16.

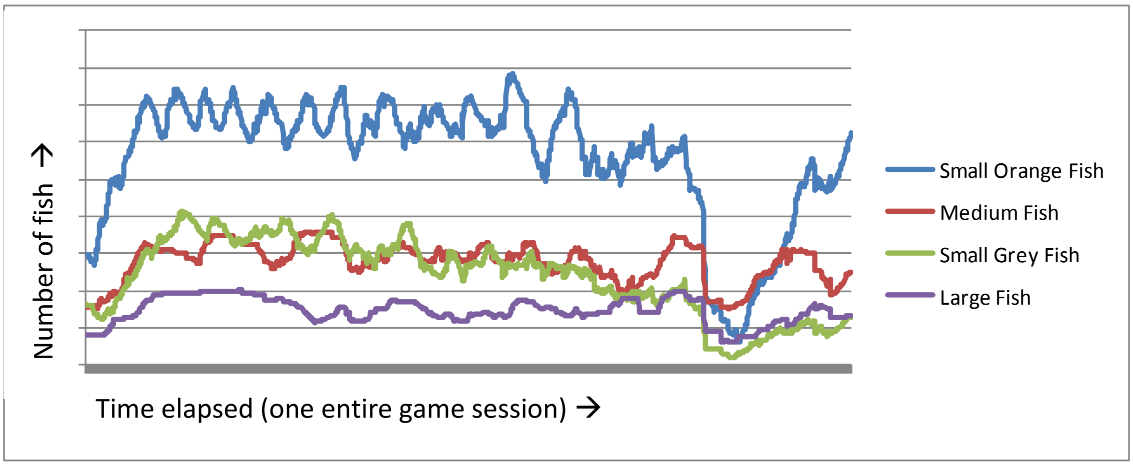

Figure 16: Player showing clear recovery from low fish stock

The difference in fish stock characteristics seems to be influenced more by age than by explicitness. The children showing the ‘stable’ fish stock characteristic were two years younger on average than the players who showed ‘recovery’. Using Bonferroni multiple comparisons, this difference shows to be insignificant ($p=.072$, $\alpha=.05$) but there seems to be a trend that age was of influence. The differences in age between the ‘fish to zero’ group and the other two groups are even less significant.

5.1.1 Game behavior variables

The explicitness did not influence the fish stock characteristics and H1 could not be confirmed, but it still could have influenced the way the game was played in other ways, for example the amount of items children bought in the shop or the number of quick season ends they used. Using a t test, the game behavior variables (see Table 6) showing the most significant differences ($\alpha=.10$) between the explicit and implicit version were determined. These are, in order of significance: the number of items purchased ($t=4,11$, $p=.006$), number of boat upgrades ($t=3,16$, $p=.011$), average money on the bank ($t=-3,03$, $p=.014$), the number of bombs dropped ($t=3,35$, $p=.016$), the number of bombs purchased ($t=3,10$, $p=.018$), number of quick season ends ($t=2,53$, $p=.030$) and the average x-position ($t=-2,11$, $p=.059$).

Figure 17 shows the significantly different variables for the implicit and explicit version of the game with their relative differences. Nearly all average values are higher for the explicit version, which means the players of that version bought more stuff, dropped more bombs and used more quick season ends. The average money on the bank and the average x-position are lower for the explicit version. All these values indicate that the players of the explicit version used more of the game's basic functionality: they bought more stuff and decided more often to skip season.

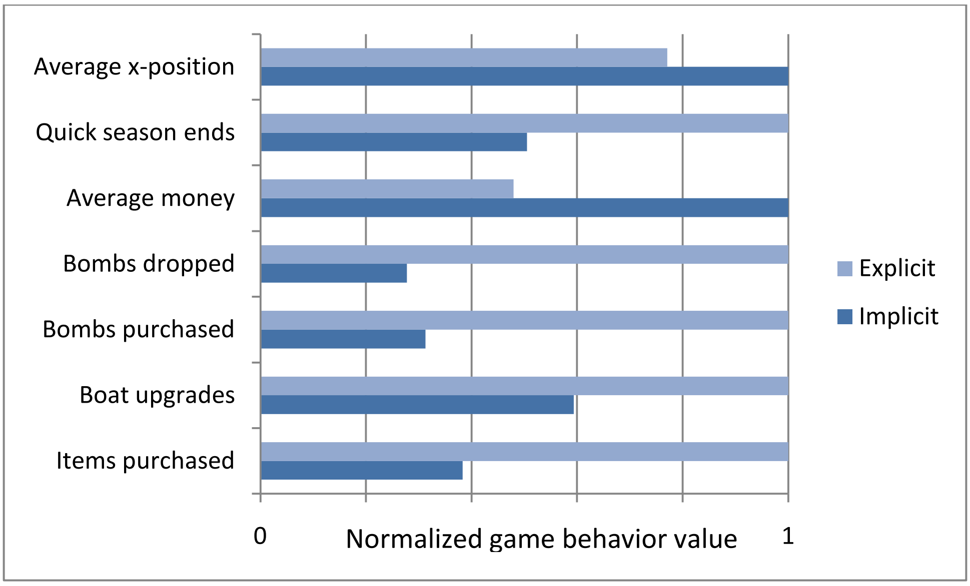

Figure 17: Relative differences of game behavior values for the explicit and implicit version, normalized to 1

All but two of the significant variables are strongly related to each other in the game mechanics. It is not strange that all these variables show similar strong correlations with explicitness, as they all are a direct result of the players of the explicit version buying more stuff on average. The number of bombs purchased and the number of boat upgrades are subsets of the total number of items purchased and the number of bombs dropped is a subset of the number of bombs purchased. When items are bought, the amount of money on the bank decreases. Figure 18 gives a schematic overview of these relations.

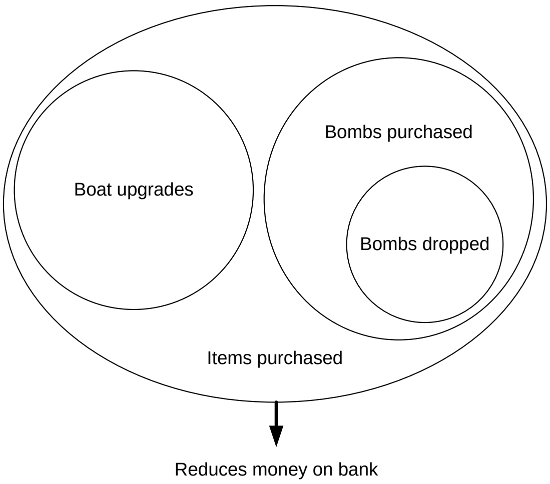

Figure 18: Relations of the variables significantly influenced by explicitness

The other two variables, the number of quick season ends and the average position in the world, are not directly related to the number of items purchased, but they are slightly related to each other in the game mechanics. When players perform a quick season end, their ship remains in the shop for the rest of the season, which reduces the average x-position.

The fact that more quick season ends were done by players of the explicit version could indicate they got the idea of fish reproduction and did not continue fishing, but instead decided to skip the season in order for the fish to restore. A distribution of the number of quick season ends can be seen in Figure 19, which confirms the idea that more players of the explicit version used quick season ends.

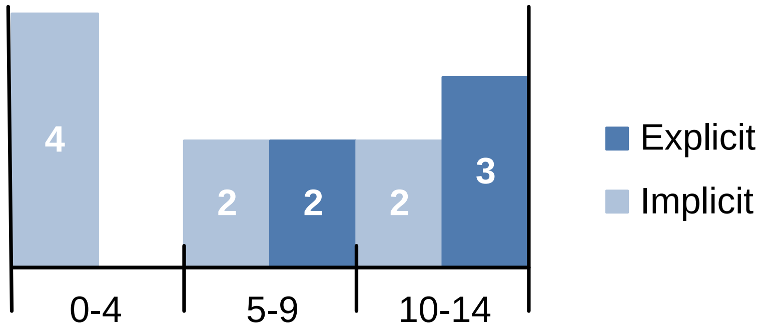

Figure 19: Number of quick season ends

When correlating the game behavior variables with age, only the number of quick season ends shows a significant positive correlation (p=.024, α=.05). This indicates that age was in general of little influence on game behavior. Using a t-test, the boys showed to have dropped significantly more bombs (p=.027, α=.05) and the number of bombs purchased (p=.053) and the number of boat upgrades (p=.057) show a trend. As more boys played the explicit version, this difference could be contributed to explicitness and not to gender.

Concluding, explicitness did not show to have any influence on the fish stock characteristics, which meant that hypothesis H1 could not be confirmed. There are indications that age was of more influence on the fish stock characteristics. The players of the explicit version did however show differences on game behavior variables which indicate more active game behavior. They bought more boat upgrades, bought and dropped more bombs and used more quick season ends. On these game behavior variables age and gender seem of little influence.

5.2 Game behavior and comprehension scores

Hypothesis H2 predicts that players showing the recovery fish stock characteristic have the best deep comprehension of the simulation, which is measured by the open questions. Table 10 shows the comprehension scores for the different fish stock characteristics.

Using Bonferroni multiple comparisons, the players in the 'recovery' group scored significantly (p=.025, α=.05) higher on the open questions than the players of the 'stable' group and shows a trend (p=.072, α=.10) when compared with the 'fish to zero' group. Between the 'fish to zero' and 'stable' group there were no significant differences. The difference in comprehension score between the players who seen most of the simulation ('recovery') and the players who have seen the least ('stable') is significant, which confirms hypothesis H2 that players showed more explorative game behavior also showed the best deep comprehension.

Table 10: Means of open question scores for the different fish stock characteristics

	Open Questions		Closed Questions		Total Score	
Fish stock characteristic	Mean Score	Std.	Mean Score	Std.	Mean Score	Std.
Fish to zero	1,00	1,00	6,67	1,26	7,67	1,04
Recovery	4,50	2,64	6,88	3,22	11,38	5,68
Stable	0,83	1,17	7,92	2,50	8,75	3,60
Everyone	2,00	2,35	7,31	2,41	9,31	3,98

The differences between the three fish stock characteristics in scores for the closed questions (true/false and multiple-choice combined) and the total comprehension scores were insignificant.

Of the variables from the data logs which characterize game behavior (see Table 6), the number of items purchased showed significant Pearson-correlations (α=.05) to the total comprehension scores and four other variables showed a trend (α=.10). When looking solely at the closed questions (factual knowledge), none of the variables shows a significant (α=.10) difference. By correlating the game behavior variables to the open questions (deep knowledge), there are two variables (items purchased and boat upgrades) showing significant correlation (α=.05) to the total comprehension scores and three showed a trend (α=.10). These variables, along with their significances and correlations, can be seen in Table 11.

Table 11: Game behavior variables correlated to comprehension scores (= p < .05, * = p < .10)**

	Open Question		Closed Questions		Total Score	
Variable	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.
Items purchased	.037**	.582	.201	.379	.041**	.623
Quick season ends	.064*	.527	.286	.344	.095*	.595
Boat upgrades	.011**	.677	.437	.236	.056*	.592
Bombs dropped	.115	.458	.188	.389	.078*	.542
Average x-position	.117	-.456	.228	-.359	.093*	-.527
Average money	.062*	-.530	.603	-.160	.166	-.408
Bombs purchased	.093*	.485	.311	.305	.105	.470

It is not a real surprise that these variables show higher comprehension scores, because these variables indicate more active game behavior, meaning these players have seen more of the game's possibilities. The variables in Table 11 are the same variables which also showed significant differences when relating explicitness to game behavior (see section 5.1.1). The variables which were higher for the explicit version of the game, also show higher comprehension scores.

Concluding, game behavior seems to be of influence on the comprehension scores. Players who showed the fish stock characteristic recovery scored significantly higher on the open questions than players who showed the stable fish stock characteristic, confirming hypothesis H2. Game behavior variables indicating active game behavior showed significant correlations with the total comprehension scores and the open question scores.

5.3 Game behavior and opinion

Hypothesis H3 predicted that players who show more explorative game behavior also will perceive the game as more fun and more challenging. Table 12 gives an overview of the different ratings given for perceived fun, excitement, difficulty and beauty for the different fish stock characteristics. The perceived fun was highest for players who showed the fish stock characteristic 'recovery' (M=5.0) and the lowest for the players showing fish stock characteristic 'fish to zero' (M=4.3). These results are in line with what was expected. However, using a Bonferroni test, the differences shown to be insignificant (α=.05) with p=.239. The small differences can have been caused by a ceiling effect with all players rating either 4 or 5 out of 5 for the fun aspect.

Excitement showed the biggest differences for the three fish stock characteristics, with the 'recovery' group rating the game the most exciting (M=4.0), while the 'stable' group found the game the least exciting (M=2.2). These results are in line with what was expected, but the difference between these two groups was not significant (p=.208). The measured instructiveness was not included in the results, because the Dutch word for instructive, (*leerzaam*), was interpreted wrong by at least two children. Instead of instructive, the children thought it meant 'easy to learn'.

Table 12: Ratings for the different aspects of the questionnaire, for the different fish stock characteristics.

	Fun	Excitement	Difficulty	Beauty
Fish to zero	4.3	2.7	1.3	4.0
Recovery	5.0	4.0	2.0	3.8
Stable	4.7	2.2	2.5	3.8

Table 13: Ratings for the different aspects of the questionnaire, for the different levels of explicitness.

	Fun	Excitement	Difficulty	Beauty
Explicit	4.8	2.4	2.4	4.4
Implicit	4.6	3.1	1.9	3.5

By correlating the game behavior variables with the opinion ratings, no significant correlations were found. Explicitness does not seem to have a significant influence on opinion either. As can be seen in

Table 13, the difference in perceived fun between the implicit (and explicit version is small and shows to be insignificant (p=.534) using a t-test. The difference for excitement, difficulty and beauty are also insignificant, with beauty showing the largest absolute difference.

Girls found the game more exciting (M=3,67) than the boys (M=2,14), with indicates a trend (α=.10) with a significance of p=.078. For fun, difficulty and beauty, gender does not seem to indicate any trends with the values for girls and boys being rather close to each other. Age also showed no significant correlations with any part of the questionnaire.

Concluding, there was no significant relation between perceived fun and excitement and the fish stock characteristics, meaning hypothesis H3 could not be confirmed. Also none of the other variables, such as explicitness, game behavior, age or gender, showed significant correlations with opinion. There was however a trend that girls perceived the game as more exciting than the boys.

5.4 Explicitness and comprehension scores

Hypothesis H4 predicts that players of the explicit version would have better factual knowledge about the game, which are measured by the true/false and multiple-choice questions (the closed questions). The difference between the comprehension scores of the players of the implicit and explicit version for the different parts of the comprehension test, along with the significances, can be seen in Table 14. As this table shows, the difference between the implicit and explicit version on the closed questions was significant (p=.026), confirming hypothesis H4. As can be seen in Table 14, the players of the explicit version also had a significantly higher score the total comprehension score and the open questions.

Table 14: Comprehension scores, compared between the explicit and implicit version

	Total Score	Closed Questions	Open Questions
Implicit	7,06	6,19	0,88
Explicit	12,9	9,10	3,80
Significance	.004	.026	.021

Explicitness was of more influence on the total comprehension score than the fish stock characteristic ‘recovery’ (which was insignificant with p=.773), but for the open questions, recovery was of significant influence as well (p=.025). Even though there was no relation found between explicitness and fish stock characteristics (see section 5.1), both witnessing recovery and explicitness seem to positively influence the open questions score.

The age of the players of the implicit version was slightly lower than the age of the players of the explicit version. When looking solely at the age of the players, there seems to be a positive but insignificant (α=.05) correlation between the scores and the age of the players (see Table 15). This correlation is the strongest for the total score and the open questions, with the latter showing a trend (p=.082, α=.10). Boys scored the highest comprehension scores on the closed as well as the open questions, but none of these differences was significant.

Table 15: Correlations between age and comprehension scores

	Total Score	Closed Questions	Open Questions
Correlation	.416	.202	.500
Significance	.157	.508	.082

Concluding, explicitness seems to have a direct influence on the comprehension scores. The significant influence on the scores for the closed questions confirms hypothesis H4. Explicitness was of more influence than the fish stock characteristic recovery for the total score and closed questions, but for the open questions both were significant. Age and gender seem of little influence.

6 Discussion

The results have confirmed two of the four hypotheses. The players who showed more explorative game behavior (those who have shown recovery) also showed better deep comprehension (H2) and the players of the explicit version had better factual knowledge than the players of the implicit version (H4). The other two hypothesis could not be confirmed. Hypothesis H3 predicted that people who showed recovery would find the game more fun and exciting, and even though the results showed higher values for recovery, the differences were too small to find any statistically relevant results. Hypothesis H1 predicted that players of the explicit version would see less of the simulation and show more 'stable' fishing behavior. Instead they fished at least as aggressively as the players of the implicit version. When looking at their game behavior, they showed to be the most active players, buying and dropping more bombs (which can harm the ecosystem), buying more stuff in general and using more quick seasons ends.

6.1 Explicitness and explorative game behavior

The most important result is that players who showed more explorative game behavior also showed better deep comprehension. This confirms the idea that in an endogenous educational game, it is important that players get the chance to explore the possibilities of the simulation. But the players of the explicit version also showed significantly higher deep comprehension than the players of the implicit version. This suggests that explorative game behavior as well as explicitness are of influence on deep comprehension. When looking at the individual cases underlying these results, it shows that the two best scoring children on the open questions both played the explicit version and they both showed the fish stock characteristic 'recovery'. This could imply that when explicitness does not limit a player's explorative behavior, it aids in comprehending what is going on in the game.

The results do not show a significant relation between the level of explicitness and the player's fish stock characteristics. Players of the explicit version did not show more 'stable' fishing behavior, as opposed to what was predicted. There are a couple of possible reasons why this might not have happened. First of all, the explicit educational purpose might not have been emphasized enough. Players of the explicit version who exhibit the 'stable' fishing behavior, only get to see a different text on the title screen. The other explicit messages are only shown as they already have dropped their fish below the 'fish to zero' threshold. This single message might not have been enough to prevent them from fishing all the way. A second reason could be that the game leaves players with too few options to explore after the boat has been fully upgraded. The only 'fun' things to do are fishing and dropping bombs. Players of the explicit version used significantly more quick season ends, which suggests that they knew fish had to recover after fishing or dropping bombs for a while.

To be able to better test the influence of an explicit educational purpose on explorative game behavior, the educational purpose should be more 'in your face' and the game should offer more possibilities to explore, making it possible for the players to obey the explicit messages, such as more sustainable fishing methods. But the question is whether such an approach is really desirable. Doing so, players of the explicit version might be guided away from exploring the simulation and will be pushed towards different parts of the game, while the results of this research show that exploring and explicitness go hand in hand. When players get the explicit messages only after exploring a part of the simulation, as was the case in Vis B.V., they seem to be able to better interpret what is going on in the simulation, while they still have to find their own ways around the problem and have to adapt the game behavior themselves.

6.2 Other effects

Even though explicitness did not influence the fish stock characteristics, the players of the explicit version were more ‘active’ players. This could have happened because the explicit educational purpose made the players more confident to explore the various aspects of the game. Another reason could be that the opening text of the explicit version told them they should not only fish. Therefore, they might have look more at what else there is to do in the game, such as buying boat upgrades. After the boat has been fully upgraded, it is easier to come in a negative spiral, which might also explain why players of the explicit version eventually dropped their fish stocks below the ‘fish to zero’ threshold.

The other important result of this research, a reconfirmation of what Leutner [Lue93] already found out, is that the explicit purpose also helps players indentify what is going on in the simulation on a lower level. Players of the explicit version were better at indentifying that fish eat each other, that the smaller fish eat the plants and that dragging the fish net can damage the plants. This also made them better at understanding the icons in the game, indicating what the fish is about to do. Some of these concepts were explicitly mentioned in the explicit messages, but the link with the icon was made by the players themselves. This indicates that they did not only reproduce the information after reading about it, but also made the link with what was happening on the screen.

The influences of explicitness and game behavior on the perceived fun and challenge are small. The ‘recovery’ group scored higher on fun and excitement, which is in line with hypothesis H3, but the difference was not statistically significant. With only thirteen respondents, Likert-scales rarely give statistical significant results and the way the questionnaire was set up did not lead to great differences in the answers. What is important to notice is that the ratings for fun and beauty were high. This means the children at least enjoyed their time with the game and even though technically it is not state-of-the-art, they liked how the game looked. Most children even started another play session after the game was over and the questionnaire was filled out, confirming they liked the game.

6.3 Statistical constraints and group diversity

That there were statistically relevant results is quite remarkable, considering the low number of subjects (N=13). This indicates that certain connections are quite strong. But it should be noted that the groups were not equal. In general, the boys played the explicit version relatively more, which could have lead to a greater difference in game behavior and comprehension scores between the explicit and implicit version. Also, the players of the implicit version seemed to have a lower sociocultural level. The children used for this research came from two different BSO (*Buitenschoolse Opvang*, English: out of school care) organizations in different boroughs of the city. The children came in groups and all children in the same room played the same version of the game. This caused that the players of the implicit version were for a larger part from a BSO which was located in a poorer borough, which can have influenced the results. It is possible that the significant effects can be contributed entirely to the differences between the two groups and it is likely the real effects are weaker than the results suggest.

One player of the explicit version was remarkably clever compared to the other children and answered nearly all questions correct, scoring remarkably higher than the other players and enlarging the differences between the two versions. This player also showed the fish stock characteristic ‘recovery’. When asked after the session, this player indicated he would also have got the idea behind the game without the explicit messages, but it is impossible to say if that would really have been the case. These factors make it risky to draw definitive conclusions, but the results do show interesting trends which offer opportunities for further research and discussion.

6.4 Theoretical and practical implications

Leutner [Lue93] already found out that an extra level of explicitness gives players the necessary guidance to comprehend what is going on in the game on a basic level. The results showed this lead to more shallow knowledge about the game, as was predicted in the hypotheses. But more explicitness was also related to the way the game was played, with the players of the explicit version using more of the game’s basic functionality. Players of the explicit version were more confident, active players.

Players who show more explorative game behavior, also have better deep comprehension. The best deep comprehension was found by players who both showed explorative game behavior and played the explicit version of the game. This implies that when adding an explicit educational purpose to a game, it is important not to limit the player’s explorative behavior. The content of the explicit messages should be limited to the first level of Bloom’s Taxonomy [Blo56], explaining what is possible but leaving the application of the knowledge to the player to find out. This way, the explorative behavior and the explicitness can go hand in hand. The explicit messages should act more as a guide than as a explanation, showing where problems could lie instead of offering the solutions. This way, they help building the abstract concepts which are so important for experiential learning [Kol84], instead of overriding them with information not grounded in concrete experiences.

When designing and evaluating educational games, it is important not to focus only on the educational results, but also on the way the game is played. As Hostetter [Hos02] notices, “It is easy to evaluate drill and practice software because the teacher can easily see that the content has been taught. However, this will bore the students and is no better than a worksheet.” He suggests that a new generation of children who are growing up with advanced computer games need new ways of learning because of the cognitive skills these children have developed through gaming. By not only looking at the comprehension but also at how the game is being played, it should be possible to discover whether the learning really took place through the game, or only through the textual information many educational games rely on. When one wants to use a experientialist approach to learning, it is important to know that the knowledge really is constructed while experiencing the game. By developing good ways to characterize game behavior and by using the data from the game itself, it is possible to relate the game behavior to the knowledge. This can be used to see what has been learned through the game and what is knowledge constructed in another way.

Even though for Vis B.V. no cutting edge technology was used, the children generally perceived the game as beautiful and fun. With many simple web-based games around nowadays, especially younger children are used to simpler looking games and do not demand three-dimensional graphics. Researchers in educational games tend to look at big commercial games as an inspiration for the technical level a game should have [BBG09]. By taking an approach often used by independent game developers, with a less labor-intensive artistic style as was done in this research, games can become attractive and fun all the same. This saves the time and energy pursuing a technical level which will probably not be reached anyways. Using such an indie-approach was suggested as well by professional computer game designers [IFH10] and this research shows it works in practice.

6.5 Future research

The research on educational computer games has been focused on learning performance, resulting in studies finding the obvious: adding text and explanation to educational games makes it easier to transmit the message [CZ04] and by adding fun mini games unrelated to the educational content, the players find the game more engaging [BBG09]. And while this can be useful changes, it is just as important to look at how the game itself has been used, instead of focusing solely on the outcomes.

This study tried to find out how an educational purpose influenced the way the game was played and how that influenced the comprehension of the educational content, but due to the small number of players, the large differences between the players and uncertainties about the relatively novel game design, it is hard to draw firm conclusions. For future research, it is useful to repeat the study with more (older) children and a better tested, more complex game design. Especially using a larger group of less diverse children is necessary to confirm if the differences between the implicit and explicit version are not contributed the factors mentioned in 6.3. Instead of looking at the effects of different levels of explicitness, instead it could be interesting to focus on the relation between game behavior and comprehension. The explicitness could be adaptive, only guiding where necessary when the game behavior shows the players are stuck in a certain situation.

Another possibility is not to compare an implicit with an explicit version, but to use explicit educational messages with apply to different levels of Bloom's Taxonomy [Blo56]. This way, it might be possible to find out if too elaborate explicit messages (on the application level) do really hinder experiential learning and whether the comprehension really gets better when the exploration actually took place in the game. It would be especially interesting looking at the long term remembering of the knowledge for the different types of explicit messages.

It could also be interesting to increase the learning results by changing the game design and the game's goals, instead of adding a layer of explicitness to the game. By including many short-term goals in the game which are related to the simulation, the players could be guided in their explorative game behavior as well. Knowing how to implicitly communicate through gaming can also increase the possibilities of including subliminal statements or educational content in commercial games. It also offers new chances for popularizing games with an educational message.

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Appendix I: Comprehension Test

Je krijgt nu een aantal vragen over het spel. Als eerste willen we graag je mening over het spel weten. Hierbij is niet een bepaald antwoord goed of fout, maar het gaat erom wat je zelf van het spel vindt. Probeer zo eerlijk mogelijk te antwoorden.

Vul de vragen in door een kruisje in één van de vijf rondjes te zetten. Hoe meer naar rechts, hoe leuker/beter je het vindt. In het onderstaande voorbeeld is het antwoord al ingevuld. Dit betekent: 'Ik vond het niet heel leuk, maar ook niet heel stom'.

Voorbeeld:

Niet Leuk O O X O O Leuk

Hoe leuk vond je het om het spel te spelen?

Niet Leuk O O O O O Heel Leuk

Hoe spannend vond je het spel?

Niet Spannend O O O O O Heel Spannend

Hoe leerzaam vond je het spel?

Niet Leerzaam O O O O O Heel Leerzaam[17]

Hoe moeilijk vond je het spel?

Heel makkelijk O O O O O Heel moeilijk

Hoe mooi vond je het spel eruit zien?

Heel lelijk O O O O O Heel mooi

Wanneer vond je het spel het leukst?

[ ] In het begin van het spel
[ ] Ongeveer halverwege het spel
[ ] Aan het einde van het spel
[ ] Altijd even leuk

[17] This question was not evaluated in the final test because not all children did not interpret it the right way. Some thought it meant 'easy to learn' instead of 'instructive'.

Je hebt net het spel Vis B.V. gespeeld. Nu volgen enkele vragen over het spel. Probeer de vragen zo goed mogelijk te beantwoorden. Als je iets écht niet weet kun je de vraag overslaan.

Vraag 1: Er volgen nu een aantal uitspraken over het spel Vis B.V. Het gaat hier om hoe de dingen in het spel zijn, niet hoe het in het echt is. Kruis aan of ze waar zijn of niet waar.

Uitspraken	**Waar**	**Niet Waar**
Door een bom te gooien gaan de vissen dood	[ ]	[ ]
Sommige vissen eten andere vissen op	[ ]	[ ]
Sommige vissen eten van de planten (koraal)	[ ]	[ ]
Kleine visjes eten soms grote vissen op	[ ]	[ ]
Grote vissen eten soms kleine visjes op	[ ]	[ ]
Vissen gaan na een tijdje vanzelf dood	[ ]	[ ]
Vissen gaan dood als ze honger hebben	[ ]	[ ][18]

Vraag 2: Planten (koraal) kunnen in het spel kapot gemaakt worden. Op welke manieren? Er kunnen meerdere antwoorden juist zijn.

[ ] Door een bom te gooien in de buurt van de planten
[ ] Door het net tussen de planten te laten zakken
[ ] Door met de boot door de planten heen te varen
[ ] Door te varen terwijl het visnet tussen de planten zit

Vraag 3: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis begroet een andere vis
[ ] De vis heeft honger
[ ] De vis is van plan een eitje te leggen
[ ] De vis zoekt een parel

Vraag 4: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis is van plan een eitje te leggen
[ ] De vis heeft honger en wil planten eten
[ ] De vis vindt de planten mooi
[ ] De vis wil schuilen tussen de planten

Vraag 5: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis begroet een andere vis
[ ] De vis heeft honger en wil een andere vis eten
[ ] De vis heeft honger en wil planten eten
[ ] De vis vindt de oranje vis mooi

[18] This question was formulated too ambiguous and not incorporated in the results. Some children interpreted this as ‘when the fish gets hungry he dies immediately’, while the fish only dies after it has been hungry for a while.

Vraag 6: Soms sterven vissen. Ze drijven dan naar boven met dit tekentje erbij: **. Hoe komt dat? Er kunnen meerdere antwoorden juist zijn.**

[ ] De vis is te oud geworden
[ ] De vis kon geen eten meer vinden
[ ] De vis werd opgegeten door een andere vis
[ ] De vis werd geraakt door een bom

Vraag 7: De bedoeling van het spel is om zoveel mogelijk geld te verdienen. Beschrijf hieronder hoe je dat volgens jou het beste kunt doen.

....
....
....
....

Vraag 8: Wat kun je volgens jou het beste doen wanneer je bijna alle vis uit de zee hebt gevist?

....
....
....
....

Vraag 9: Wat gebeurt er als je alle kleine vissen uit de zee hebt gevist?

....
....
....
....

Vraag 10: Wat gebeurt er als je te veel planten hebt kapotgemaakt?

....
....
....
....

De volgende twee vragen gaan niet over het spel zelf, maar over de echte wereld.

Vraag 11: Welk van de volgende uitspraken is waar? Er kunnen meerdere antwoorden juist zijn.

[ ] In het spel leggen visjes eitjes, in het echt doen ze dat niet
[ ] In het spel kun je een vissoort bijna helemaal wegvissen, in het echt kan dat niet
[ ] In het spel kun je een bom op de vissen gooien, in het echt gebeurt dat niet
[ ] In het spel zitten maar vier vissoorten, in het echt zijn er veel meer

Vraag 12: Welk van de volgende uitspraken is waar? Er kunnen meerdere antwoorden juist zijn.

[ ] Bijna alle vissoorten worden met uitsterven bedreigd

[ ] Grote zeedieren als haaien en walvissen worden met uitsterven bedreigd

[ ] Zoogdieren zoals panda's en olifanten worden met uitsterven bedreigd

[ ] Sommige vissen worden met uitsterven bedreigd omdat mensen te veel vis vangen

Ten slotte hebben we nog een paar persoonlijke vragen.

Hou oud ben je?	…………………
Wat is je geslacht?	Jongen / Meisje
Hoe vaak speel je computerspelletjes?	Nooit / Soms / Vaak / Heel Vaak
Hoe vaak gebruik je een computer?	Nooit / Soms / Vaak / Heel Vaak

Bedankt voor het spelen van Vis B.V. en het invullen van de vragenlijst!

Appendix II: Answer model

Vraag 1: Er volgen nu een aantal uitspraken over het spel Vis B.V. Het gaat hier om hoe de dingen in het spel zijn, niet hoe het in het echt is. Kruis aan of ze waar zijn of niet waar.

Uitspraken	**Waar**	**Niet Waar**
Door een bom te gooien gaan de vissen dood	**[X]**	**[ ]**
Sommige vissen eten andere vissen op	**[X]**	**[ ]**
Sommige vissen eten van de planten (koraal)	**[X]**	**[ ]**
Kleine visjes eten soms grote vissen op	**[ ]**	**[X]**
Grote vissen eten soms kleine visjes op	**[X]**	**[ ]**
Vissen gaan na een tijdje vanzelf dood	**[ ]**	**[X]**
Vissen gaan dood als ze honger hebben	**[X]**	**[ ]**

Vraag 2: Planten (koraal) kunnen in het spel kapot gemaakt worden. Op welke manieren? Er kunnen meerdere antwoorden juist zijn.

[X] Door een bom te gooien in de buurt van de planten

[ ] Door het net tussen de planten te laten zakken

[ ] Door met de boot door de planten heen te varen

[X] Door te varen terwijl het visnet tussen de planten zit

Vraag 3: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis begroet een andere vis

[ ] De vis heeft honger

[X] De vis is van plan een eitje te leggen

[ ] De vis zoekt een parel

Vraag 4: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis is van plan een eitje te leggen

[X] De vis heeft honger en wil planten eten

[ ] De vis vindt de planten mooi

[ ] De vis wil schuilen tussen de planten

Vraag 5: Wat betekent dit tekentje, dat soms in het spel bij een vis verschijnt:  **?**

[ ] De vis begroet een andere vis

[X] De vis heeft honger en wil een andere vis eten

[ ] De vis heeft honger en wil planten eten

[ ] De vis vindt de oranje vis mooi

Vraag 6: Soms sterven vissen. Ze drijven dan naar boven met dit tekentje erbij: . Hoe komt dat? Er kunnen meerdere antwoorden juist zijn.

[ ] De vis is te oud geworden

[X] De vis kon geen eten meer vinden

[ ] De vis werd opgegeten door een andere vis

[ ] De vis werd geraakt door een bom

Open questions: relevant terms are between [brackets]

Vraag 7: De bedoeling van het spel is om zoveel mogelijk geld te verdienen. Beschrijf hieronder hoe je dat volgens jou het beste kunt doen.

Door [vis te vangen], maar wel te zorgen dat er [vis overblijft] in de zee. Als er [geen vis meer is, dan kun je geen geld meer verdienen]. Als er weinig vis is moet je even [wachten tot er nieuwe vis geboren wordt] of een [seizoen overslaan]. Je moet [niet teveel planten kapot maken] of één [bepaalde vissoort helemaal wegvissen]

Vraag 8: Wat kun je volgens jou het beste doen wanneer je bijna alle vis uit de zee hebt gevist?

[Wachten] tot de [vissen eitjes leggen] en er [nieuwe vissen bijkomen] of een [seizoen overslaan] zodat er weer meer vis is.

Vraag 9: Wat gebeurt er als je alle kleine vissen uit de zee hebt gevist?

Dan [sterven] de [grote vissen] omdat er [geen eten] meer voor hun is. Zij [eten de kleine vissen].

Vraag 10: Wat gebeurt er als je te veel planten hebt kapotgemaakt?

Dan is er [geen eten] meer voor de [kleine vissen] en zullen ze van de honger [sterven].

De volgende twee vragen gaan niet over het spel zelf, maar over de echte wereld.

Vraag 11: Welk van de volgende uitspraken is waar? Er kunnen meerdere antwoorden juist zijn.

[ ] In het spel leggen visjes eitjes, in het echt doen ze dat niet

[ ] In het spel kun je een vissoort bijna helemaal wegvissen, in het echt kan dat niet

[ ] In het spel kun je een bom op de vissen gooien, in het echt gebeurt dat niet

[X] In het spel zitten maar vier vissoorten, in het echt zijn er veel meer

Vraag 12: Welk van de volgende uitspraken is waar? Er kunnen meerdere antwoorden juist zijn.

[ ] Bijna alle vissoorten worden met uitsterven bedreigd

[X] Grote zeedieren als haaien en walvissen worden met uitsterven bedreigd

[X] Zoogdieren zoals panda's en olifanten worden met uitsterven bedreigd

[X] Sommige vissen worden met uitsterven bedreigd omdat mensen te veel vis vangen