

# Digital Games That Teach: A Critical Analysis

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## Preface

Since late 2005 (I am at the Institute for Media and Communication Science of TU Ilmenau since November 1, 2005) the Multimedia Applications Group<sup>1</sup> has put some focus on Digital Games. This reflects a decision of the institute backed up by the university authorities to make Digital Games a central topic of research and development.

In the summer term 2006, we have been delivering lectures on Digital Games at TU Darmstadt, at BA Mannheim and, naturally, at TU Ilmenau.

The group has won the bid for an excellence in research project<sup>2</sup> at TU Ilmenau focusing on “Security in Online Games”.

Within the first 6 months of the year, we came up with three publications on Digital Games; two of them have been invited talks<sup>3</sup> on international conferences in Japan and Germany, the third one has been winning a best paper award.

Diploma theses and media projects on issues of Digital Games are in progress.

Though the first nine months of dealing with Digital Games might be seen quite successful, many problems remain open and there is still an urgent need for strategic decisions.

The field of Digital Games is a huge application domain with a large number of customers worldwide establishing the most rapidly growing and dynamically evolving market in the media industries. It has already left the box office behind. Digital Games are complex IT application systems for the game playing domain.

It is beyond imagination that a single research group could cover the relevant topics of Digital Games research exhaustively. There is a necessity to concentrate.

Seeing Digital Games both as complex IT systems and as entertainment media that may have a certain social impact, it makes sense to ponder those games that have been intentionally designed towards social effects – games that are developed for educational purpose.

This report surveys first investigations that were undertaken to set the stage for the group’s own scientific engagement in edutainment.

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<sup>1</sup>in German: Fachgebiet Multimediale Anwendungen

<sup>2</sup>TU-interne Exzellenzförderung

<sup>3</sup>Another one is in preparation: “Games That Do Not Exist” to be given at the 24th Annual Conference of the ACM SIG on Design of Communication, Myrtle Beach, SC, USA, Oct. 2006.



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### **Abstract**

What a great dream: playful learning, even learning when playing . . . ! Within the prosperous field of digital games, those games developed with an educational purpose just fill some niche. No need to worry! Increasing public awareness of the potential social impact of digital games will also direct more attention to edutainment, to games that teach. But what about the current state of the art? Aren't there many those games around? How do they appear? How does it feel playing them? In particular, how do players learn when playing games that teach? The author has studied six German educational games in some depths. The outcome is disappointing: It does not work.

The stage is set for a systematic analysis to arrive at insights which may lead to a substantially different design of games with an intended educational effect. There is an obvious need for a digital games science.



# 1 Playing and Learning – A Bird’s Eye View

It is an old dream of didactics to make teaching and learning easier both for teachers and for learners, respectively [Com 1638].

Information and communication technologies have been setting the stage for (computer and network) technology enhanced learning. Approaches to e-learning begin to change classroom practice, vocational education, and life-long learning.

The enormous growth of the digital games industry has given the efforts to establish technology enhanced learning a quite new momentum: playful learning. What about employing games for learning?

This question may be seen a little surprising. Whenever we play, we learn.

When you play racing games, sports games, or beat’em up games such as, e.g., SOUL CALIBUR, you train certain motor skills. When you play CHESS, GO, or SHOGI, you train your brain, your abilities of systematic thinking, of careful analysis, and of strategy and tactics. When you play development games such as AGE OF EMPIRES, CIVILIZATION, SETTLERS, or SIMCITY, you learn to maintain optimization problems such as balancing resources.



Figure 1: Playing the MMORPG LINEAGE

Players report even higher level learning experiences in online games such as LINEAGE (figure 1): “Here I was given the chance to transform and to shine.

This program, this game was allowing me to spread my wings. It was teaching me more about myself and what kind of person I wanted to be than school or parents or any other force that was supposed to be guiding me through my teenage years. In Lineage, I could be the type of person I wanted to be, without fear. I could be confident and cocky, I could be a leader.” [Gen 2006]

This sounds like game playing may change not only your level of knowledge and skills, but your personality.



Figure 2: I am receiving my first reward for my very first good deed in FABLE

In games such as FABLE, you have many choices of your avatar’s behavior. In response to your behavior, you receive feedback like appreciation or contempt from other characters in the game.

Is it you who acts or is it your avatar? Who is the good or the bad boy or girl? Richard Bartle, one of the fathers in spirit of contemporary role playing games, said: “At the persona level of immersion, the virtual world is just another place you might visit, like Sydney or Rome. Your avatar is simply the clothing you wear when you go there. There is no more vehicle, no more separate character. It’s just you, in the world.” (cited after [Wal 2006]) So, in figure 2 it’s truly me.

However exciting, the aspects mentioned above are not those we are going to focus in the present report. We are not looking for learning en passant, but for willfully arranged learning experience—digital games that are designed to teach.

## 2 Playing and Learning – An Intuitive Account

How does the world of edutainment appear at a first glance? When searching the Internet for “Games That Teach” one may find by far more than 1000 games. So, that seems to be a prosperous field with a lot of exciting offers, or not ...?

Not at all! A closer look reveals an enormous number of games that are not really pleasant to play. Pedagogy has killed the fun.

Can we do better? To attack this question seriously, we urgently need some systematization of the expectations and requirements we have.

According to the insight that players usually learn when playing (see section 1), we arrive at a few minimal requirements:

- For a game that teaches, there should be some declaratively described body of learning content.
- For every body of learning content, there should be some established and widely accepted criteria of learning success.

Notice that we do not claim that the criteria of success shall be implemented in the game like, for instance, tests of various forms. Whether or not evaluation<sup>4</sup> of the learning effect shall be integrated is quite another issue.

Nowadays, the quality of game playing is a decisive factor for the acceptance of games that teach. On the highly competitive digital game market, the standards are set up very high. Accordingly, the expectations of the players are high.

- Every digital game that teaches has to belong to some category of games—the term *genre* is frequently used—which is familiar to the audience.
- In its category, the educational game has to meet the standards of games on the market.

High quality standards shall not be confused with high resolution graphics and realistic physical simulations. The perception of digital games is considerably more involved.

It depends very much on the game category<sup>5</sup> what players do expect. In fun racing games such as *CRAZY TAXI* they do not expect realistic environments. And in fantasy games, it does not make sense to expect all creatures to look like their realistic counterparts, because most of them did never exist. No one expects *SUPER MARIO* to jump according to gravitation and to the laws of physics.

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<sup>4</sup>Feedback is a vary important issue in teaching and learning, in general, and it is a critical one in technology enhanced learning. To the author’s very best knowledge, there is not yet any scientific work on educational feedback in games that are employed for educational purpose.

<sup>5</sup>The author does not agree with the current ad hoc usage of the term *genre* in the literature, mostly in the regular print media. However, an introduction of an alternative terminology—the author uses the terms *type*, *genre* (in a narrow sense), and *class*—is without the scope of the present report.

One of the biggest mistakes in games for educational purposes is to cause frustration originating from a conflict between game play and teaching material. If this happens, it discredits edutainment possibly for ever—at least in the eyes of the present player.

- Interactions of learning should not interrupt the flow of game play and should not disturb the player’s immersion.
- Interactions of learning shall not hinder the player from reaching her/his goals, but shall be supportive.

It may be clear, but is obviously necessary to be mentioned, that

- a game should not fall apart into its playing part and an educational add-on.
- Interactions of learning should appear as inherent constituents of the play.

The subsequent analysis will exhibit how difficult it seems to be to meet those minimal requirements, though all of them appear natural if not mandatory.

It might easily be the case that meeting all requirements at the same time is simply impossible.

### 3 Case Studies in Edutainment

The following six digital games have been studied in some depth. Four of them are reported below in the sections named in the table. The games are ordered by the year of publication shown in the third column.

Game	Publisher	Year	Section
PHYSIKUS	HEUREKA Klett	1999	3.1
BIOLAB	HEUREKA Klett	2001	–
BRAND IM HAFEN	HEUREKA Klett	2002	3.2
CHAOS AM SET	HEUREKA Klett	2002	–
GENIUS UNTERNEHMEN PHYSIK	Cornelsen Software	2004	3.3
GENIUS TASK FORCE BIOLOGIE	Cornelsen Software	2005	3.4

These games, taking the age of the earlier ones into account, are among the best looking games in edutainment the author has seen within his investigations of the last about 4-6 weeks. They represent different types worth to be discussed in more detail.

At a first glance, all these six games look nice and, possibly, pleasant to play.

### 3.1 Case Study PHYSIKUS, 1999

The learning domain of PHYSIKUS is physics, more precisely, lessons in five branches of physics.

The game looks a bit old-fashioned, but is designed with a lot of dedication. The virtual world is made of tapestry as shown in the figures 3 and 4.

The game is a point & click adventure with basically three different types of player activities. One may click to give the direction of movement, in case the mouse cursor has the form of an arrow. In this case, the scene is updated. In case the mouse cursor is in hand shape, one may either click to an object or click and hold the button to move some object.

The human player sees the game scenery from a typical first person perspective such as in so-called ego-shooters, but no weapons are employed.



Figure 3: The first steps into the virtual world of PHYSIKUS are strictly guided.

The guidance in the game is extremely rigid. In the beginning, there is nothing else possible than going to the house shown in figure 3 and entering the building.

Being inside the house, the player can only go to the working table on which some gadget (background screen in figure 3) is found. Here, one gets access to the learning material; the gadget is understood the player's wearable computer.

Furthermore, the player gets some more basic information about his mission in the game, in addition to the information given prior to game play.

Essentially, the plot is a science fiction story in which the player has to work for energy supply to solve a problem of the virtual world in which he just arrived.



Figure 4: Finding documents in the romantic world of PHYSIKUS

As in many other adventure games, there are a lot of things to collect<sup>6</sup>. Figure 4 shows on the background screen two fancy buildings. The middle screen displays the interior of the rightmost house where the document shown on the front screen may be found.

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<sup>6</sup>The culture of point & click adventures has established a particular attitude: pick up and take with you whatever you can get, never mind whether it seems reasonable to do so or not.

Whenever facing a task during game play, the player may consult the learning section of the game.



Figure 5: The learning section PHYSIKUS

This section is clearly separated from the game itself. The background screen of figure 5 gives an impression: There are 5 subsequent lessons. In every lesson, learning material of the form shown on the front screen of figure 5 is sequentially presented.

The PHYSIKUS digital game provides the motivation to learn the lessons. But learning the lessons remains as tedious as it always used to be.

Naturally, within this digital environment the learning material is arranged in multimedia form like in several e-learning environments.

One may see PHYSIKUS as an e-learning environment with five lessons of physics. The game appears as a motivation to study the lessons. One might easily ignore the whole game and just deals with the e-learning stuff. The evaluation of PHYSIKUS as an e-learning system is quite another issue beyond the limits of the present report.

In the very end, it turns out that PHYSIKUS is not a digital game that teaches. The setup falls apart into its two components: e-learning stuff and science fiction game.

### 3.2 Case Study BRAND IM HAFEN, 2002

BRAND IM HAFEN (German for Fire in the Harbor) is also a point & click adventure. The plot is of the type of conventional criminal stories where no private investigator and no police is involved. The hero resolving the case has been found—the player.

Note that CHAOS AM SET is very similar; there is no need for any separate discussion. Maybe, the one or the other similarity will be worth to be mentioned.

In BRAND IM HAFEN, the player has a female avatar named Janny who browses the harbor, talks to other characters, and collects whatever she can get.



Figure 6: NPCs talk to each other in scripted scenes of BRAND IM HAFEN.

Janny is waiting in the background on the screen in figure 6, where two non-player characters (NPCs, for short) talk to each other. Scripted scenes frequently interrupt the game flow.

The target knowledge of BRAND IM HAFEN as a game that teaches is not that clearly specified: everyday knowledge. This has to be taken into account when comparing BRAND IM HAFEN (or CHAOS AM SET, similarly) to other games with the ambition to teach, because others are facing established expectations of what belongs to a certain corpus of knowledge that has to be taught at the least. This does not apply to everyday knowledge.

Many objects are found that carry valuable information. The player's avatar may use and sometimes combine objects in many ways. This includes tearing off some page of a book about mushrooms to present this page to some avatar for convincing the NPC of some case of poisoning.

However, talking to NPCs is the player's or, more precisely, the player's avatar's main activity.



Figure 7: Talking to NPCs when playing BRAND IM HAFEN

When talking to an NPC, one may present her/him objects such as the mushroom visible on the right screen in figure 7.

To gather sufficient information to resolve the case, the player needs to bring the avatar to certain places such as a ship, a submarine bunker, or at the very end of the game to some meeting point with the main suspect.

The game state space does contain several bottlenecks, i.e. comparably small subspaces of states which have to be passed necessarily before another important point can be reached.

For illustration, there is no regular way to enter the ship of interest in the harbor. In almost all game states, the game mechanics prevents the player's avatar from entering the ship. The only way is to go there together with another avatar who is operating the food stall. But she is making the offer only under the condition that the player—his avatar—presents her some material resolving the case of food poisoning.

Here is another bottleneck—in fact two subsequently depending bottlenecks. Close to the very end of the game the player's avatar needs her boss to arrange some meeting with the main suspect. He is not willing to do so. Therefore, the

avatar needs to present him some label of a certain drug bottle to extort him. This label can be and must be found and taken very early in the game.

Another bottleneck is contained in something like a fuse box (see figure 8). When the player opens the box all light bulbs are turned of. A fuse is missing. After inserting a fuse (which has been found earlier in the game) at position 1, it is possible to switch on some of the bulbs. However, at position 6 some bridge is missing. Only some candy wrapper may help—a bottleneck to solving this puzzle.



Figure 8: An electrical circuit that has to be closed necessarily

The puzzle itself is something like a bottleneck, because it has to be solved for opening some door.

The bottleneck concept is crucial to the game *BRAND IM HAFEN*, and so it is to *CHAOS AM SET*. In the latter game, for instance, a fax plays an important role in an early stage of the game. It is necessary to receive the fax, but there is no paper in the fax machine. A single white sheet of paper occurs in an earlier scene where, in fact, the occurrence of this sheet of paper does not really make any sense in this particular scene. It is just introduced to implement a bottleneck.

On the one hand, bottlenecks are a component of the game rules invoked for player guidance as a way to implement some dramaturgy despite the relative freedom of the player to act. This is the way to present some narrative.

On the other hand, the bottlenecks are crucial to the integration of learning content into game play. In some of the bottlenecks, players are forced to use some knowledge. In some of these situations, they have to use knowledge about the story gained during game play. In certain other situations, the knowledge invoked is everyday knowledge which is not fully provided within the game play.

For illustration, the player needs to have an imagination of how a chewing gum might be used to make a copy of a simple key.

Similarly, in *CHAOS AM SET* it is assumed that the player knows a very little about *CHES*S and how a magnetic compass works, e.g.

The game, in general, and the arrangements of bottlenecks, in particular, provoke the human player to use some of her/his everyday knowledge. If the knowledge does not suffice, the game flow breaks down. The game gets stuck.

Whenever learning takes place in playing the game BRAND IM HAFEN<sup>7</sup> (or CHAOS AM SET, similarly), this is offline learning. If you do not know anything about CHESS, e.g., go and ask.

Basically, players do not learn much about the everyday knowledge addressed by those games. The games trigger the usage of particular knowledge. At best, one might say that the games serve as training environments for the application of the players' knowledge.



Figure 9: BRAND IM HAFEN – the showdown scripted

When the player has completed all exercises successfully, the case resolves in a scripted showdown scene from which figure 9 displays a snapshot.

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<sup>7</sup>There are a few exceptions. Players who did not know anything about mushrooms and the risk of food poisoning learn a little bit within the game. They may even learn about some sorts of mushrooms and which one might be mistaken for the other one.

### 3.3 Case Study GENIUS UNTERNEHMEN PHYSIK, 2004

The game GENIUS UNTERNEHMEN PHYSIK is a real-time development game which requires strategic and tactical thinking and which is played in a very simple point & click fashion. The game GENIUS TASK FORCE BIOLOGIE may be seen as its sibling.

The field of studies in the game under discussion in this section are some branches of physics.

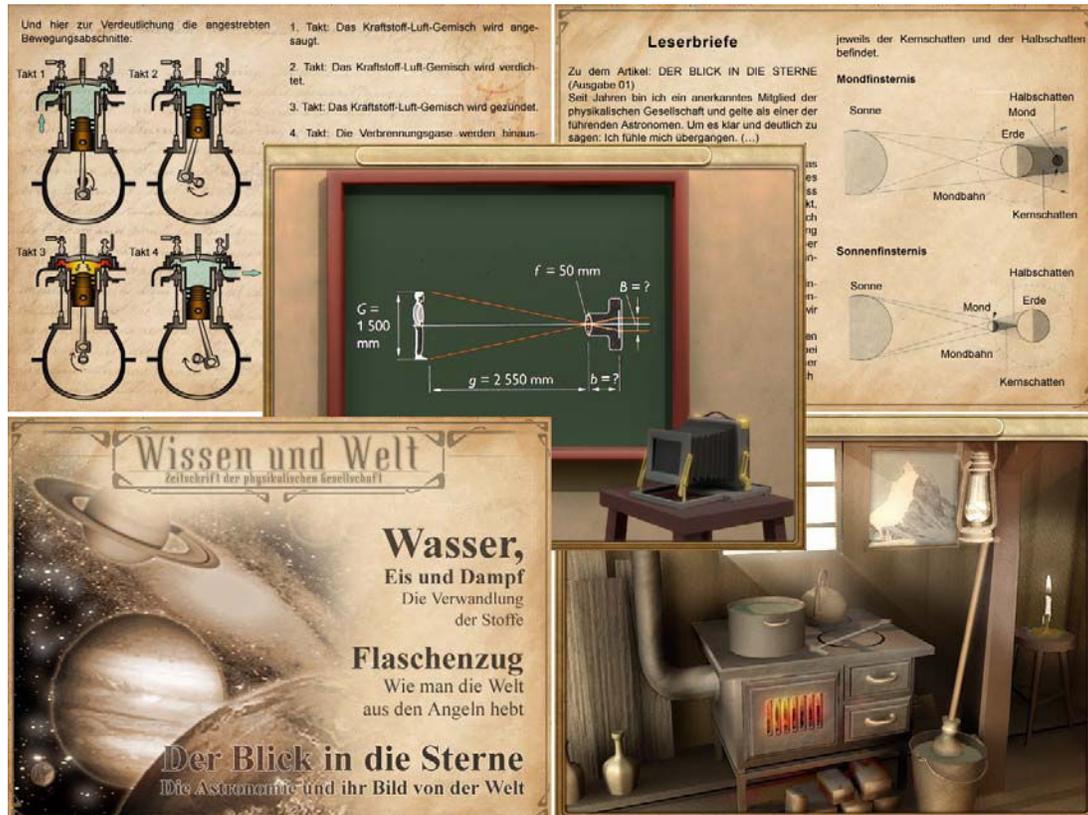


Figure 10: Learning Material in GENIUS UNTERNEHMEN PHYSIK

This edutainment game contains a large amount of systematically prepared learning material. There are among other sources about 500 files of the type on display in figure 10.

Some of the material is quite involved. There are helpful illustrations and stories embedding the presentation of scientific content. The system fakes the player's conversation with some historical personalities who provide information which may be used when working on certain exercises.

Most learning tasks are really interesting—naturally, depending on the players' taste and, not to forget about, their background knowledge.

To players who like development games, this game has some appeal. From the perspective of point & click development games, this is not a bad one.

The player's task is to establish an enterprise and to keep it expanding under the conditions of progress in science and technology as well as in a competition which is getting harder and harder. In the beginning, there is only a small bicycle workshop.



Figure 11: A very special problem in GENIUS UNTERNEHMEN PHYSIK

Expanding the economy requires developing the urban environment because there is a need for resources including working power.

The game has its economy simulation engine running in the background which manages the consumption of resources vs. the output of virtual money.

When playing the game, one quite early gets some impression of unfairness in the sense that it seems impossible to keep the economy balanced (in contrast, cf. a fair simulation on page 19). Whatever the player is doing, (s)he is running into bankruptcy. What helps is the solution of some exercise in physics. Those are offered randomly just briefly before the financial breakdown.

This raises the question for the role of those exercises and their integration into game play.

To study this question in depths, two extreme case studies have been undertaken: (A) developing an economy without settlement, i.e. without any working power and (B) building up an urban settlement without any production.

In case study (A), the game engine exhibits several bugs as shown in figure 11. There are no workers in any of the bicycle factories erected. The control panel on the right hand side shows under the date two pairs of figures: 0/0 and 0/95. The first pair is giving the number of workers and the living space built so far. The second pair is representing the number of workers employed and the number of positions available. There are 95 positions, but no workers at all. Nevertheless, one of the factories (in figure 11, the middle one in the row of five) is strikebound.

The case study (B) provides even more interesting insights. When nothing is produced and every available amount of money is always immediately invested into expansion of the settlement, the economy runs straight into bankruptcy.



Figure 12: Financial reward for learning in GENIUS UNTERNEHMEN PHYSIK

There are several internal game state variables of importance to the economy simulation that are not visible to the player. The main variable which is visible is shown in the control panel in front of the \$ sign: the balance of the bank account.

The value of this variable determines which player moves are possible. At a balance below \$ 25 the player is paralyzed.

The experiments undertaken exhibit the role of solving learning tasks during game play. Figure 12 is showing an exercise on the background screen. After the task has been completed successfully, 5000 virtual dollars are paid to the bank account (see the control panel of the screen in front).

Solving other exercises may result in setting internal variables as illustrated by means of figure 13. Those internal variables may, for instance, increase the income per sold unit. Thus, those changes normally contribute to the alleviation of economic bottlenecks.



Figure 13: Setting internal variables in GENIUS UNTERNEHMEN PHYSIK

The background screen of figure 13 shows an exercise related to construction details of bicycles. The successful solution results in a new setting of marketing figures as announced in the front screen: We are now selling more bicycles, ... although we are not producing any.

The gist of these extreme case studies was to find out how and for what purpose studies in physics are integrated into the development game GENIUS UNTERNEHMEN PHYSIK.

### 3.4 Case Study GENIUS TASK FORCE BIOLOGIE, 2005

Very much like its sibling game GENIUS UNTERNEHMEN PHYSIK, the game GENIUS TASK FORCE BIOLOGIE under investigation in the present section does contain a huge amount of well-prepared learning content. The present game, in contrast to its predecessor, contains much of the content in form of finer granularity. This allows for more flexible presentations of composite learning objects.

In the case of GENIUS TASK FORCE BIOLOGIE, the field of studies are several branches of biology.



Figure 14: Learning Material in GENIUS TASK FORCE BIOLOGIE

As in the case study before, we ask for the role of learning in the game or, more precisely, for the dovetailing of learning and game playing.

To the author's big surprise, the findings are substantially different from those reported in section 3.3.

The player's task in the first and easiest level of GENIUS TASK FORCE BIOLOGIE consists in the renaturation of some African savannah area. The region is badly devastated.

Renaturation is expensive. Therefore, the task is to develop some industry that provides output which may be sold such that the income allows for stepwise investments in renaturation.

The task is presented in the left screen of figure 15. The small screen with the black frame shown on this screen gives an impression of the actual devastation. The right screen of this figure displays the initial situation where work begins.



Figure 15: Learning Material in GENIUS TASK FORCE BIOLOGIE

As in every development game, there runs some simulation engine in the background. In contrast to GENIUS UNTERNEHMEN PHYSIK (see section 3.3, page 15), the simulation of GENIUS TASK FORCE BIOLOGIE is fair.

In addition to the simulated economy, the natural environment is simulated. Plants grow and animals return to the recovered environment in dependence on the progress of renaturation. Players may enjoy returning elephants and giraffes.

Very much like in GENIUS UNTERNEHMEN PHYSIK, there are some internal parameters of the simulated process of economic development of the present game which can not be controlled directly. Those parameters, for instances, are prices the player can get for sold goods.

Exercises are presented to the player and the successful completion of an exercise may set those internal parameters to new values.

For illustration, successfully assembling a microscope as shown in figure 14 results in an increase of the price of grain.

This particular role of solving exercises may not become completely clear to players who do not think of the game as a complex dynamic process with internal and external variables, about direct and indirect control, and about other concepts of process engineering.

Those players might ask themselves what the solution of an exercise is used for.

There occurs, i.e., an exercise where the player is asked to provide a correct scientific classification of wolves. Wolves do not appear in the game, and the knowledge of such a classification is never used again. The microscope mentioned does occur in more than one exercise, but it never appears in playing the game.

It is the author's suspicion that learning and game playing fall apart. Learning is not properly integrated into the game. Players fascinated by the development task may easily forget about learning for a while. But how to test this hypothesis?

One may try to play the game GENIUS TASK FORCE BIOLOGIE without solving any of the exercises. Does that work?

Here is a demonstration documented by a few subsequently taken screenshots.



Figure 16: GENIUS TASK FORCE BIOLOGIE– game playing without learning

During this first steps of game playing, the renaturation rate which original was at 19% drops down to a minimum of 15%. The reason is that for the development of the settlement, several trees have been cut. The last screen shows first efforts of resolving the devastation problems.

Future steps lead to a prosperous economy which allows for comprehensive renaturation. The upper part of the two scenes on display in figure 17 illustrate the recovery of the natural environment. The settlement is growing as well.



Figure 17: GENIUS TASK FORCE BIOLOGIE– renaturation in progress

The player finally arrives at 100% of renaturation (see the lower-most figure in the control panel shown on the right side of the screen in figure 18).



Figure 18: GENIUS TASK FORCE BIOLOGIE– great success without learning  
Other figures in the mentioned control panel document the success in business.

There is living room for 464 workers completely filled. There are 465 working positions and 461 workers are employed. There is more than enough electricity and water supply. The bank account shows a balance of more than \$ 40000.

The five zeros in a row above the monetary figure exhibit that–throughout the whole game play–not a single learning task has ever been considered.

There are several more minor problems not discussed in the present report. To get an impression, have a look at the two screenshots in figure 19.



Figure 19: GENIUS TASK FORCE BIOLOGIE– remains of devastation

Although 100% renaturation are reached, both scenes document remains of devastation. In a parallel game play reported in the right hand scene, the player has undertaken some efforts of renaturation. Whatever the player invests in the name of the environment, the figures never change. When the simulation engine for the habitat arrives at 100% of renaturation, it seems to widely ignore what the player does.

But these peculiarities distract us from the main subject under consideration; further details are suppressed.

To sum up this experiment with the game GENIUS TASK FORCE BIOLOGIE, one can enjoy playing the game with full success and satisfaction without paying any attention to the learning task. Even worse, the game proves to the player that learning is not essential.

This seems to be a quite disastrous result for a game which has been designed for an educational purpose.

## 4 Analysis and Evaluation

As said in the present paper's abstract on page 1, there is an urgent need for a *digital games science*. Such a science needs for its discourse an appropriate language that allows for expressions from the terminology of media science, from informatics, in general, and from artificial intelligence, in particular, and finally and foremost from all together at once [Jan 2006]. The present case studies exemplify what is needed.

Even the most recent games among those investigated evince severe faults in high level design. Have a look at the white text in the upper part of the screen in figure 20: “SPIEL PAUSIERT”. Unbelievable! *The game pauses.*



Figure 20: Separation of learning from playing in the digital game GENIUS UNTERNEHMEN PHYSIK; it is the same in GENIUS TASK FORCE BIOLOGIE

The player is told to be a businessman. It is said that learning is important for a flourishing business. Tasks have to be solved that require some specific knowledge. But when the player becomes interested in particular background knowledge and searches his documents, there pops up the alert that learning is out of game activity. The games pauses.

It can't get much worse. Not only that playing and learning are falling apart, the player is explicitly pointed to the fact that learning is something special.

What did we find out in the case studies of the preceding four subsections? Instead of listing all details and going into the depth of the one or the other peculiarity such as the phenomenon illustrated by figure 20, our analysis abstracts three key phenomena:

- The parts of learning and game playing fall apart. Learning appears as a separate activity and needs actions different from the other moves a player may take.
- Learning does not take place in the game. Instead, the game is more like a testbed where the application of knowledge may be trained.
- Driven by the intention to present some narrative and to implement certain dramaturgy, the player's freedom to move is reduced almost to a minimum; game playing mutates to path finding.

The second phenomenon occurs in all of the investigated games to some extent. One might think of developing a taxonomy of digital games taking among other aspects the degree of in-game learning into account. Steps towards a taxonomy<sup>8</sup> of digital games are out of the scope of the present report. We confine ourselves to a subsequent discussion of the three abstracted phenomena above.

The first (and third) phenomenon is the main problem of the *PHYSIKUS* game. In fact, the publisher is delivering an e-learning system with some related game. They missed the target.

In the two above-mentioned criminal investigation adventure games, there is not so much learning material. Therefore, the first phenomenon does not occur.

Compared to other criminal investigation games in a point & click fashion<sup>9</sup> such as, for instance, *AGATHA CHRISTIE: AND THAN THERE WERE NONE*<sup>10</sup>, *BLACK MIRROR*, and *THE DA VINCI CODE*, there is not considerably more learning involved in the games *BRAND IM HAFEN* and *CHAOS AM SET*.

In the games *GENIUS UNTERNEHMEN PHYSIK* and *GENIUS TASK FORCE BIOLOGIE* as well, playing and learning fall badly apart as shown (figure 20).

As said above, the second phenomenon occurs in all of the investigated games. As learning may be avoided completely in *GENIUS TASK FORCE BIOLOGIE*, this may be seen as an exceptionally extreme cases.

In *BRAND IM HAFEN* and *CHAOS AM SET*, the testbed character of the games becomes most explicit. In [Gra 2003], the author directs the player explicitly to offline learning<sup>11</sup> and to subsequently testing the results when playing.

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<sup>8</sup>It might easily be that the first phenomenon implies the second one. This were be leading directly to some hierarchy in such a taxonomy of games.

<sup>9</sup>Several survival and horror games are somehow close in spirit to those point & click adventures, but usually much more complex. An in-depth study of games such as *CALL OF CTHULHU* requires a more elaborated analysis.

<sup>10</sup>in German: *AGATHA CHRISTIE: UND DANN GABS KEINES MEHR*

<sup>11</sup>“Schau mal in deinem Physikbuch oder in einem allgemeinen Lexikon unter dem Begriff ‘Farbenlehre’ nach.”, *ibid.* p. 12

The third phenomenon of trading the freedom of game playing against the presentation of a narrative is known from many digital games. Players frequently complain long cut scenes that interrupt the flow of the game, especially in first-person shooters and survival/horror games.

It has an particularly negative effect if it becomes obvious that the restricted freedom of the player's choice to act is mostly due to the designers' or developers' intention to force the player to deal with learning tasks. Learning becomes the bad part of the game.

The rigidity of player guidance is particularly bad in BRAND IM HAFEN, CHAOS AM SET, and PHYSIKUS.

The choice of some framework of digital games description is helpful to make the problem clear [Jan 2006].

With a game  $G$ , there is given a finite set of potential activities that may take place. In PHYSIKUS, for instance, there are only steps into four directions allowed, straight forward ( $F$ ), left ( $L$ ), right ( $R$ ), or turning backward ( $B$ ). The possible steps are indicated by the appearance of the mouse cursor. Facing a door, the player may either open or close the door ( $D$ ). In front of certain gadgets, the player may start an (usually unknown) action ( $A$ ) by clicking to the gadget. This option, again, is indicated by a change of the mouse cursor. There are a few more possibilities suppressed here. The system may react with certain activities drawn from a finite repository. Those are written in brackets below such as [*alert*], e.g.

At the beginning of the game PHYSIKUS, the player is forced to enter the house (front screen in figure 3), to find the gadget on the table (screen in the back), and to activate it. The minimal sequence of steps to do so is  $FFDFFFFDFLFFA$ .

Every game play  $\pi$  appears as a finite sequence of moves of the alphabet  $A$  of possible activities (more conventionally: moves), i.e.  $\pi \in A^*$ .

Every game  $G$  may be seen as generating a formal language  $\Pi(G) \subseteq A^*$  of potential game experiences.

For complex games  $G$  and under realistic conditions of game playing, large parts of  $\Pi(G)$  are never played. It remains open whether or not the part of  $\Pi(G)$  really played within the *cybernetic system* of the players and the game [Gil 2005] may be described in sufficiently clear terms.

Let's call the set of really played action sequences within  $A^*$   $\Psi(G) \subseteq \Pi(G)$ . What about  $\Psi(G) \subset \Pi(G)$ ? In fact,  $\Psi(G)$  forms the space of experience which is of interest (see [Jan 2006] for more details).

With the concatenation  $\circ$  of actions or moves, one may consider  $[\Psi(G), \circ]$  as an algebra. Several equivalence relations may be introduced. The semantic equivalence  $\sim$  means that two sequences of actions lead to exactly the same state.

In the game PHYSIKUS, for instance, there are infinitely many sequence  $\pi$  in  $\Psi(G)$  which are equivalent to  $FFDFFFFDFLFFA$  conventionally expressed by  $\pi \sim FFDFFFFDFLFFA$ .

However you play PHYSIKUS, when you play it to an end, your game playing experience must have an initial part equivalent to  $FFDFFFFDFLFFA$ .

This is the strongest form of a bottleneck as informally discussed in our preceding case studies.

$\Psi(G)$  might still contain some incomplete game play. In case a game has well-defined goals such that one may distinguish completed playing experiences like those where the showdown is reached,  $\Psi^c(G)$  is used to describe those sequences. It usually holds  $\Psi^c(G) \subset \Psi(G) \subset \Pi(G) \subset A^*$ .

$\beta \in A^*$  is called a *strong bottleneck* of a given game  $G$ , exactly if it holds that all  $\pi \in \Psi^c(G)$  have an initial sequence  $\pi_0 \preceq \pi$  such that  $\pi_0 \sim \beta$ .

It is known from automata theory that strings in an algebra such as  $[\Psi(G), \circ]$  may be identified with states of a related automaton. We suppress those details.

Based on the game state concept for any game  $G$ , one may introduce further important equivalence relations. A usually helpful approach is to call states equivalent, exactly if some variable has a certain value. This may be extended to many variables, because the family of equivalence relations is closed under intersection.

In BRAND IM HAFEN, for instance, one may easily recognize that a game state is crucial in which (a) the player's inventory contains a mushroom, (b) it contains the page teared off the book about mushrooms, and (c) the last action just performed is "combination" of these two items. (Combination is the name of one of the player's ground actions.) This is the moment when the player becomes able to resolve the food poisoning problem.

If two sequences of actions  $\pi_1$  and  $\pi_2$  reach states with this property, their equivalence is denoted by  $\pi_1 \approx \pi_2$ .

There is at least one sequence of actions  $\gamma$  wich leads to such a game state. The background screen of figure 7 shows a moment where this state has just been passed.

For any game  $G$  with its set of actions  $A$  and any equivalence relation  $\approx$ , a sequence of actions  $\beta \in A^*$  is called a *bottleneck* with respect to  $\approx$ , exactly if it holds that all  $\pi \in \Psi^c(G)$  have an initial sequence  $\pi_0 \preceq \pi$  such that  $\pi_0 \approx \beta$ .

The game BRAND IM HAFEN has a bottleneck with respect to the particular equivalence relation introduced above.

More generally, all games considered in the present paper have many bottlenecks with respect to a large number of varying equivalence relations.

How severe bottlenecks are depends very much on the equivalence relation. From another perspective, a bottleneck is severe if the set of equivalent states is comparably small.

If the sets are too small, it may be difficult for a player to find the bottleneck and pass it.

Sometimes, the problem is not the difficulty to find the bottleneck, but the rigidity with which the player is driven through the bottleneck. This applies, for instance, to the first exercises in GENIUS UNTERNEHMEN PHYSIK, where the completion is enforced because the economy goes bankrupt otherwise.

On a higher level, similarities of bottlenecks may be considered, because those similarities might contribute to fun or to boredom, in dependence on many details and, in particular, on the human recipient.

This approach although being quite interesting is left to future investigations.

Until this point, we have been speaking about the algebra of actions, but dealt with elementary actions only. It is usually quite difficult to tell a game using a terminology which, so to call, resides inside  $A^*$ .

One might tell a game of CHESS like that, for instance, listing the moves  $Kf3 d5 g3 Bg4 b3 Kd7 Bb2 e6 Bg2 Kgf6 0-0 \dots$ . This, by the way, is the beginning of the match between G. Kasparov and the computer Deep Blue on May 3, 1997. But it is also the beginning of a match between Kortshnoi and Sax in Tilburg, 1989.

Usually, we talk on higher levels of expression, even in CHESS, where it may be a pleasure to tell a surprising knight fork, e.g.

The sequence of actions  $FFDFFFFDF$  in PHYSIKUS may be reported as just “go to the house and enter”. More complex activities might be better told in such a fashion.

For providing a firm basis, we have to introduce layered levels of languages with corresponding alphabets  $A_0, A_1, A_2$ , and so on.  $A_0$  should be  $A$ .

There are mappings from expressions over some  $A_i$  to expressions over some  $A_j$ , where  $i \leq j$ . Homomorphisms are preferable.

Here, we do not go into much detail. Instead, a few practically important cases are sketched.

First, there are abstractions. Abstractions are erasing homomorphisms usually mapping from  $A_0^*$  (i.e.  $A^*$ ) to  $A_1^*$ . Abstractions leave certain activities out. In complex games, you don’t recognize all moves. You always speak about homomorphic images of what you have really been playing.

Second, there are generalizations. In complex development games including GENIUS UNTERNEHMEN PHYSIK, actions are parameterized by positioning information such as coordinates on the underlying grid. Generalizations map from  $A_0^*$ , for instance, to a higher level, say  $A_1^*$ . Expressions that are different in  $A_0^*$  may have identical images in  $A_1^*$ . This makes it easier to identify regularities in game play—an important issue of understanding fun [Kos 2005].

Longer sequences  $a_k a_{k+1} a_{k+2} \dots a_m$  over  $A_0$  have sometimes a description in higher lever terminology  $A_j$  such as “opening a bottle”, “climbing up a ladder”, and many, many others.

If  $h$  is a homomorphism mapping  $a_k a_{k+1} a_{k+2} \dots a_m \in A_i^*$  to  $b_l \dots b_n \in A_j^*$ , one calls  $b_l \dots b_n$  the *meaning* of  $a_k a_{k+1} a_{k+2} \dots a_m$ . Vice versa,  $a_k a_{k+1} a_{k+2} \dots a_m$  is the *implementation* of  $b_l \dots b_n$  provided by an inverse homomorphism.

Not every sequences from  $A^*$  has a meaning, but every meaning must have an implementation.

This terminology is laying the cornerstone for an explication of many of the problems with the games under investigation.

As an application of a few technicalities introduced, let us have a closer look at the game GENIUS TASK FORCE BIOLOGIE.

For every learning activity in the game, we may find an appropriate language representation and ask for its implementation. “Assembly of a microscope” may be chosen as a case.

There is some homomorphism  $h$  and some sequence of actions  $a_r \dots a_t$  with  $h(a_r \dots a_t) =$  assembly of a microscope.

Going through a complete game play, one may separate all learning activities and all other activities that are game playing in a more narrow sense. One should do that on a level on which the playing experience may be told to another human.

We arrive at two sets of terms on some language level  $A_j$ . One set contains descriptions of what happens when dealing with learning tasks.

We may now look at the implementations of the terms of the one and of the other set. Those implementations are always sequences in  $A^*$ . We get two resulting sets of strings in  $A^*$ .

Interestingly, these two sets of strings have no substrings in common, i.e., playing and learning are implemented in two completely different ways. These activities do not interfere. The coupling in the game mechanics by means of the simulation engine is an artificial one.

In the example where  $a_r \dots a_t$  implements the assembly of a microscope, no action  $a_s$  ( $r \leq s \leq t$ ) is ever used in any game playing moment.

To sum up this approach, the introduction of description languages, of the concepts of meaning and implementation, and of homomorphisms relating implementation and meaning allows for a localization of substantial problems by studying the images of inverse homomorphisms. It can be easily demonstrated how playing and learning fall apart.

This terminology would also allow to explicate a deep dovetailing of playing and learning by explication the intersections of the image sets of inverse homomorphisms.

In the positive case—which has not been found in the present case studies—the terminology allows for deeper investigations into the way in which playing and learning are interrelated. This has to wait until games arrive that properly teach.

## 5 Summary and Conclusions

There are already several games that are said to contribute to playful learning. But because it is quite obvious that players usually learn also when playing games that are designed without even the slightest pedagogical intention, there is a necessity to pose more explicit requirements to (digital) “games that teach”. In the author’s opinion, many of the games like those reported in the present paper do not deserve to be called educational games. Our expectations are higher.

The main deficiency discovered lies in the quality of dovetailing learning and game playing. It easily falls apart.

There is the proper chance to arrive at digital games that truly teach when

- a large part of the knowledge to be acquired is of immediate value to game playing, i.e., it is used in the one or the other place of the game, and
- the particular activities of learning are not obviously separated from the player’s actions of playing the game.

A scientific approach which sees digital games both as edutainment media and as complex IT application systems at the same time may provide an appropriate language for analysis and synthesis of games that teach.

Digital games as IT application systems may be reasonably seen as generators of (sequences of) game playing experience, very much similar to formal grammars that generate formal languages.

The quality of integrating learning into game playing may be characterized by properties of those formal languages representing game play. The stage is set.

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