Learning by Playing: Can serious games be fun?

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Abstract: During the past two years we developed a physics game following a unique design principle. Many educational games currently available on the market solely focus on knowledge transfer following a behaviourist principle (Annetta, 2010). The learner is confronted with more or less demanding tasks which are solved using the trial and error method (Skinner, 1938). Learning success is directly assessed using a simple feedback system („right“, „wrong“). Furthermore the audio visual quality of interactive learning software often can't keep up with video games today's target group has become accustomed to. We decided to take a different path.

Since fun of play is considered as one of the key elements of an elaborated game playing experience (Vorderer et al., 2004), we decided to design a fun filled and action packed learning game built around a serious topic: renewable energies. The content of the game is based on the physics curriculum while the graphical and audio visual quality of "Ludwig" was designed to match common triple A games. A simple formula „learning goal = game goal“ defined the core game mechanics. Based on a constructivist paradigm "Ludwig" offers challenges in an interactive 3d world: learning takes place in an authentic context (McLellan, 1985). Players are allowed to explore the game world, to experiment in virtual laboratories and to solve problems freely while their actions directly lead to consequences and positive feedback by the game. The players actions leave a trace in the game world fostering individual experiences of self-efficacy (Bandura, 1977).

Numerous feedback iterations with the target group consisting of students and teachers secured a satisfying level of quality regarding the learning content, the gameplay and the look & feel of "Ludwig". We decided to use an iterative design principle which empowers players to become game designers (Wagner, 2009). By applying qualitative and quantitative methods we gained insights in the applicability of variable quality assurance strategies. Students reflected on the playability of the game, on the usability of the interface and finally on motivational aspects (learning motivation, interest for physics). Teachers reflected on the potential benefits and problems of using "Ludwig" in class. The results of the formative (quality assurance workshops) as well as the summative evaluation (assessment of motivational, cognitive and learning processes) show that "Ludwig" can foster learning processes if game based learning is combined with established teaching methods and material.

Keywords: game based learning, serious games, intrinsic motivation, instructional design

1. Introduction

Digital games are rarely used in education. They can however serve as a powerful instructional tool for potential use by all ages. What are the opportunities of using learning games in the classroom? Annetta (2010) states that "games can bring about a lifelike experience to problem based learning that cannot be replicated in the traditional classroom". The learning process occurs unnoticed by the respective learner while he or she becomes invested in a game. That is, students do not realize that they are learning embedded content (Annetta, 2010; Fromme et al., 2008). Interactive learning environments are able to foster deep learning processes by integrating knowledge content in a technology mediated setting (Annetta, 2007). Today's students feel safe in using these settings since they grow up as "digital natives". The so called digital divide separates media savvy students from teachers mainly using analogue learning methods. Prensky (2001) summarizes this emerging problem by stating "today's students are no longer the people our educational system was designed to teach". They are used to process new information fast, are able to multitask and prefer to use hypertext media systems like the internet. Digital learning games account for these needs and habits.

To fill this gap we developed a research scenario to study motivation and knowledge transfer factors in educational games for children from 10 to 14. We want to facilitate the learning process based on an optimal playing experience, i.e. enhancing the motivation of students concerning the school subject physics in a playful way (Desurvire et al., 2004).

How are we able to motivate learners to deal with complex learning content by their own choice? One of the key theories referring to self-regulated behaviour is the self-determination-theory (SDT) by Ryan and Deci (2000). It addresses basic conditions that are relied to the process of self-motivation. The authors postulate three basic needs: competence, autonomy and relatedness. If these needs are satisfied, deeper forms of motivation emerge: “no single phenomenon reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn” (Ryan & Deci, 2000). Intrinsic motivation can be regarded as prerequisite for deep learning processes. Perceived autonomy, competence and relatedness also play a major role in the process of interaction with games (Przybylski et al., 2010). “Ludwig” accounts for these needs and offers players an open game world, adequate levels of difficulty and a profile system similar to social network profiles. All these factors contribute to a valuable playing experience.

The concept of proximal development (ZPD) is another theory applicable in the context of game based learning. It defines the difference between a child's actual and potential levels of development (i.e., what a child can do alone and with the assistance of an expert/computer). According to Vygotsky (1978), play creates a broad ZPD, both in cognitive and socio-emotional development. This finding bears a lot of potential regarding the application of games in the school context.

Another important concept, which is directly linked to intrinsic motivation, is the flow experience. “Flow” is a mental state that occurs when persons are fully immersed in an activity. The flow theory basically states that activities can be per se rewarding, with no need for external regulation (Csikszentmihaly, 1990). Fun of play is highly correlated with experiences of flow, enhancing the enjoyment of media consumption (Vorderer, 2004). Bearing that in mind we built the game mechanics around the learning content, concentrating on the optimization of the playing experience. Furthermore the game system was based on design principles commonly used by game developers. Based on a model of media enjoyment by Vorderer (2004) and game design rules by Salen & Zimmerman (2003) we propose using the following game design principles for creating a meaningful playing experience (see game design framework on page 5):

1. Developers should aim at creating an immersive game environment.
2. The gameplay should be story driven.
3. Players should be able to interact with objects in an authentic context.
4. The game system should give immanent feedback to the player's actions.
5. The controls, the interface and the level of difficulty should be scalable depending on the player's individual needs.

2. Challenges

The challenges of digital game based learning are frequently discussed in the scientific community. There are some counter arguments concerning the use of digital media in context of school. Salomon (1998) argues that interactive learning scenarios require “self-discipline and self-monitoring skills facing routine learning tasks”. These tasks can demand too much from students if teachers are not able to provide enough guidance and support.

What hinders teachers in using game based learning tools in class? Since digital media depends on technology, there are some prerequisites that have to be met. Baek (2008) identified six factors we should keep in mind when using games as instructional tool in class: inflexibility of the curriculum, potential negative effects of gaming, students' lack of readiness, lack of supporting materials, fixed class schedules, and limited budgets.

Another important challenge is to foster transfer effects from the virtual context to the actual learning context (school, home). Wagner (2009) highlights the importance of converging game and learning goals. The equation that the learning goal should be the same as the game goal plays a major role in the design process of learning games. Following this assumption, Linderoth (2010) claims that “progressing in a game being able to take actions and reach built-in game goals is not solely a matter of learning”. Achieving game goals is a matter of competences that are gained within the system. If the purpose of sophisticated game based learning is to impart knowledge, then good game design should focus on presenting the learner meaningful problems and learning content.

Designing effective hypertext and media systems for displaying learning content can be a difficult task. Hypertext systems offer a large degree of freedom and flexibility. This freedom can however lead to “lostness”. Poor design and usability shortcomings enhance feelings of disorientation. Furthermore user's individual mental models and cognitive learning styles should be taken into consideration when building these systems (Otter & Johnson, 2000). A confusing layout can also lead to a cognitive overload in terms of user's perception abilities. In this case learners are not able to process all of the

information presented, since cognitive resources are limited. Being lost is a complex problem, which should be taken seriously.

3. Ludwig

"Ludwig" is an interactive 3D-adventure game built around a serious topic: fossil and renewable energy (www.playludwig.com). The development process is following three primary principles of gameplay: freedom to learn from errors, freedom to experiment, and freedom to make an effort (Osterweil, 2007). Furthermore, we emphasize actual developments concerning educational standards for physics. The heart of our project lies in its iterative game design (Wagner, 2009). "Ludwig" was utilized and optimized gradually based on the feedbacks of participatory students and teachers. Usability, fun of play, motivational factors and learning progress were investigated. Possible cognitive transfer effects (interest, self-efficacy) were measured. We attached a sample screenshot below in order to illustrate the look and feel of "Ludwig":

Figure 1: sample screenshot

The learning progress in our game is mapped by knowledge points, which are received when important quests are solved or if resources are found by the player. The more he or she explores the virtual world the more content is unlocked in the knowledge base. It describes important facts related to energy (combustion, wind energy...). These facts orient on the curriculum for physics. Concerning the design of our knowledge base, usability criteria (based on national DIN norms) are taken into consideration.

Our main design perspectives were threefold:

1. We wanted to create a game that can deliver a high quality gaming experience on a competitive basis. The audio-visual quality of "Ludwig" should stand a comparison with "triple A" (high profile blockbuster) games our target group is used to play.
2. Furthermore we wanted to make a learning game that actually makes fun. That's the reason why we took findings from media psychology into consideration.
3. Finally we wanted to foster learning processes that are free from boundaries set by the game or from external regulations.

"Ludwig" focuses intrinsic motivation by implementing the learning goal deeply into the game. It offers an interactive environment, a virtual playground for the respective learner. Players collect resources (coal, wood, paper...) hidden in the game world in order to use them in a laboratory. The laboratory can be seen as "game within the game" - it simulates physical models in an experimental context. By using this setting, science can be made accessible for users. It is however important to support autonomous learning methods by giving the player full control over his actions without implementing any time limits or sequential arrangements. From a constructivist point of view, learning processes depend on the grade of involvement in the respective activity. While solving contextualized tasks student's skills are developed by working on the problem through authentic activities (Duffy & Cunningham, 1996). The entry level of "Ludwig" itself provides plenty of opportunities for learners to work immediately on realistic problems like starting a fire by means of combining resources found in the game world. Later levels deal with water, wind and solar energy.

3.1 Iterative Design Process

One of the main challenges in creating an educational game lies in the fact that game development aims at optimizing intrinsic motivation at the expense of constantly questioning important aspects of the game mechanics as well as the game narration. This is usually done through a fast paced and user centered iterative design approach in which professional play testers provide constant evaluation of the playability of the game that is fed back into development in real time (Fullerton et al., 2004). In contrast, instructional design starts with the identification of instructional goals and ends in a summative evaluation (Dick et al., 2008). By virtue of the underlying process model, game design therefore focuses on optimizing fun whereas instructional design focuses on optimizing the achievement of instructional goals. As a result, educational games that are based on instructional design processes tend to lack the element of fun. On the other hand, if educational games are designed for fun, they quite often deviate from the original instructional goals resulting in games with quite often only limited educational value.

In order to overcome this problem, we decided to employ a novel iterative game design process that adds the element of an instructional evaluation within the play testing phase of the game development (Wagner, 2009). The quality assurance process therefore relies on the feedbacks from students and teachers and tries to optimize fun as well as the achievement of instructional goals. Based on the play testing feedbacks we aim at identifying problems and enhancing the overall quality of "Ludwig" step by step during the development phase. In this way we are able to respond to students' and teachers' personal needs and expectations in an efficient way (Triantafyllakos et al., 2008).

4. Summary and overview

Video games provide virtual environments in which opportunities for action are manifold. The growing participation in these environments suggests that learning games can be highly motivating, if learning games take into account important features that are responsible for creating meaningful playing experiences. Based on the current research we present a study which deals with motivational and cognitive consequences of using the physics game "Ludwig" in the classroom. Furthermore we aim at developing a game based learning framework for future application in the context of serious game design.

We specifically predict, that "Ludwig" is able to foster student's learning motivation and leads to transfer effects concerning knowledge and self-efficacy. Our interest however also lies in improving the game based on the feedbacks by students and teachers and in identifying potential problems regarding the application of our learning game in an educational context.

5. Method

The methodology is both qualitative and quantitative. We applied quantitative methods which make use of numbers to precisely operationalize values of a particular variable (answers in questionnaires) for further statistical computations, while also using qualitative methods which allow for a systematic interpretation of the meaning of verbal material (interviews, workshops). We decided to combine elements from both approaches in order to get a holistic view on the acceptance and effects of our game.

The quality assurance process relied on feedbacks from students and teachers. By means of these feedbacks we aimed at identifying problems and enhancing the overall quality of "Ludwig" stepwise during the development phase (iterative approach). To assess the overall fun factor and playability we adapted quality criteria developed by the "Federal Office for the Positive Assessment of Computer and Console Games" (BUPP), which is a service agency of the Austrian Ministry of Economy, Family and Youth. This institution offers guidance for parents and kids by rating video game titles and hosting a review database on this site. These criteria describe the following key aspects of gameplay: audiovisual quality, controls, fun of play, level of difficulty, performance, playability & suitability.

The user based design process should enhance the playability of our learning game. Practical issues relating to the school context (technical resources, lack of IT-rooms) were likewise considered by accounting for the teacher's perspective.

Students and teachers were asked to join the project from the very beginning. Ten school classes took part in the iterative didactic design process of "Ludwig" by expressing their individual view of the game during play-testing-sessions. Three main iterations were conducted between spring 2011 and early 2012. Semi structured interviews with teachers reflected the acceptance and application of learning games in class. Students from different high schools received questionnaires referring to the usability of the game (interface, control of avatar), to the playing experience (fun of play, immersion), to motivational factors (intrinsic motivation, self-efficacy, interest for physics) as well as to knowledge gains. For measuring self-efficacy and interest we used questionnaires from the Pisa studies (PISA

assesses to what extent students at different educational levels have acquired essential knowledge and skills). For measuring intrinsic motivation we utilized a questionnaire developed by the Austrian Knowledge Management Institute (Bedek, 2010). Fun of play, perceived level of difficulty and immersion were determined using a questionnaire on game experience by Klimmt (2008).

6. Results

We would like to report the results of the summative evaluation which concentrated on transfer effects concerning knowledge, interest and self-efficacy. Testing took place at the beginning and the end of term. By means of exploring these variables in a scientific design, we were able to evaluate the potential benefits of integrating digital games in the curriculum (using "Ludwig" in class). Additionally, we are still working on facilitating the usability and quality of the gaming experience. The qualitative results of the first four iterations of the iterative game design process are displayed on page 5. Feedbacks from students and teachers are likewise described.

6.1 Quantitative Results

During the last winter term we conducted a summative evaluation, which analysed the quality and impact of the final version of our game. Our goal was to measure possible knowledge transfer effects, changes in interest for physics and changes in student's self-efficacy concerning physics. To put it in other terms, we wanted to know if "Ludwig" alters motivational and cognitive factors: can we pick up students at their actual individual knowledge and motivational states and get them to the next level in a playful way?

Four classes from two different schools participated in this process. In order to evaluate these effects, we follow a classical pre-post 2x2 design. This means that student's knowledge concerning the subject physics, perceived instructional quality, self-efficacy and student's interest for physics were to be investigated at the beginning and the end of term. Additionally we manipulated the grade of feedback by the respective teacher. Transfer effects concerning knowledge, interest and self-efficacy were defined as dependent variables. Testing time and grade of feedback by the teacher were defined as independent variables. Game experience and sex were controlled statistically.

Differential analyses were calculated in order to show if and how strong potential transfer effects are (after "Ludwig" was played in class). The results of a multivariate analysis of variance show, that "Ludwig" leads to a knowledge transfer, but only if the playing sessions are well reflected by teachers and students ($F_{3,78}=10.32$; $p<.01$). The game content has to be linked to existing physical problems. The difference between testing 1 ($M=4.33$; 10 points maximum) at the beginning of term and testing 2 ($M=6.41$; 10 points maximum) at the end of term was only significant for the class which reflected the game content and was supported by the teacher in course of playing "Ludwig".

Regression analyses with stepwise exclusion of variables were conducted in order to map potential dependencies among game related variables. Fun of play and overall game rating were defined as dependent variables. Sex, game experience, perceived level of difficulty, playability and motivational aspects were defined as predictors. The resulting models were able to explain 60% of variance regarding fun of play and 36% regarding overall game rating. The individual extent of effort ($\beta=0.43$), playing experience ($\beta=0.28$) and immersion ($\beta=0.18$) have a positive influence on fun of play. The overall game rating is influenced by the subjective level of difficulty ($\beta=0.56$) and the perceived playability of "Ludwig" ($\beta=0.36$).

6.2 Qualitative Results

We interviewed 8 teachers concerning the opportunities and challenges of using learning games in class. 200 Students received check lists and questionnaires referring to the audiovisual quality of our game, the playability, motivational factors, positive and negative aspects of "Ludwig" and finally to suggestions for improvement.

Students mainly highlighted the main figure of our game, they specifically liked the animation and the looks of "Ludwig" (44%). The high degrees of freedom in exploring the game world and in solving tasks also led to a high level of satisfaction (22%). Problems were reported as far as controls (43%) and navigation (18%) are concerned. The text material was considered to be too extensive (39%).

Teachers see "Ludwig" as valuable supplement to established teaching methods. According to all involved teachers our learning game is able to trigger self-reliant learning strategies (100%), to enhance student's motivation concerning physics (100%) and to make students curious about physical principles (100%). Possible obstacles that stand in the way of a broad application in educational

settings are tight schedules (100%), poor it infrastructure at schools (75%) and lacking resources for preparation (37%).

The iterative design process was constantly fed by feedbacks of teachers and students. The overall progress of the quality assurance efforts is displayed below.

Figure 2: iterative design process

The figure above shows the progress made thanks to the four main iterations. The quality of the graphics and controls were tweaked significantly based on the feedbacks by our student game testers. All five quality indicators, which were derived from a catalogue by the BUPP, were used to calculate the overall fun factor of "Ludwig" which improved from 44% to 64% in course of the iterative design process.

6.3 Game Design Framework

Based on our findings and the literature review we would like to propose the following framework for future learning games.

Figure 3: game design framework

Three characteristics should be taken into consideration regarding the development and application of learning games in school:

1. game characteristics: immersive environment, adaptive controls, embedded learning content
2. student characteristics: playing experience, interest for subject, learning effort
3. teacher characteristics: time for preparation, tight schedules, discussion of game content

Since immersion is a well discussed media experience phenomenon, we would like to further define our understanding and definition of the construct: immersion stands for a high level of fun, an appropriate level of difficulty, an interactive game system which gives the user immanent feedback about his or her actions and a story driven gameplay.

7. Conclusion

Learning games are valuable instructional tools, which offer great opportunities in the context of using new technologies for teaching and learning. In our opinion, the strengths of game based learning methods are manifold:

1. Learning games are able to strongly motivate learners regarding a specific topic.
2. Learning games offer opportunities for learners to work immediately on meaningful problems.
3. Open learning systems foster self-regulated learning skills.
4. Using current technology's possibilities we can create immersive gaming experiences.

"Ludwig" can be seen as a first small step in trying to improve our school system. It encourages players to become self-reliant and autonomous. Learning takes place in a situational context

By conducting our project we aimed at supporting players at gaining knowledge in a playful way. The content of the game is based on the physics curriculum, while the game mechanics focus fun of play and intrinsic motivation as key elements. The target group consisting of teachers and students contributed significantly to the game in course of quality assurance workshops. Students, teachers, scientists and physics educationalists helped creating a scientific framework for the application of serious game based learning methods in school. Students reflected on the playability of the game, on the usability of the interface and finally on motivational aspects (learning motivation, interest for physics). Teachers reflected on the potential benefits and problems of using "Ludwig" in class. In addition to these workshops we conducted a summative evaluation of transfer effects concerning motivational aspects and potential knowledge gains.

Data retrieved from the quality assurance workshops showed that "Ludwig" is overall well accepted by our target group. Central game experience values concerning the playability of the game, fun of play and immersion indicate that the iterative design process was successful regarding the adaptation of the game content, level of difficulty, controls and quest system to the needs of players. Generally speaking players are intrinsically motivated to succeed at in game tasks and goals. Relations between these variables also reveal interesting patterns, which stress the important role of the entertainment value of educational software. Fun of play should be taken into consideration when designing game based learning content. Finally, first results from the summative evaluation support our hypothesis that "Ludwig" is able to impart knowledge in the field of renewable energies. Motivational factors however stayed constant and did not change in course of playing sessions. These finding comes surprisingly and should be investigated in future studies.

This paper presented the potential benefits and challenges of digital game based learning. Findings from different scientific fields have been taken into consideration in order to ensure the overall quality of our project. We mainly wanted to know if "Ludwig" is able to foster student's learning motivation and interest, which should eventually lead to a higher learning effort. We described new findings supporting the idea of using games as valuable supplement for conventional instructional tools.

8. References

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