Virtual Sports Instructor: A 3D Serious Game for Physical Education with Game Master Support

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Abstract: Recently, a need for new teaching models and a new role of the teacher has evolved. Serious Games offer a new concept for game-based learning. Using state-of-the-art 3D-technology, it is possible to create virtual environments in which students can practice what they learn in theory at school or at institutes of higher education. In the HMWK[1]-funded project "Serious Games für die Hochschule", we create a Serious Game for students who study to become a physical education teacher. In the game they can internalize the typical sport lesson procedure, learn how to treat pupils and practice different sport exercises. An instructor can adapt the game at runtime according to the player's performance (Game Master). The Game Master is able to view important statistics, to modify the difficulty or to trigger events from inside the game. Thus, the instructor has a completely new control over the game.

Motivation

The concept of Serious Games has become more and more popular during the last years. Serious Games offer various fields of application, like Serious Games for education (Wendel et al. 2010), for sports & health (Exergames, Wiemeyer & Goebel, 2010), for training and simulation, or for social software. There are prominent examples of Serious Games in the fields of nutrition awareness (Baranowski et al. 2008), energy awareness (Enercities[1]), political awareness (Global Conflicts series[2]), or in the military sector (Americas Army[3]). Furthermore, there are motivational Serious Games, like for support of cancer patients (Re-Mission[4]), and finally Serious Games for education (Scoyo[5]). Companies also use Serious Games for training of business processes (Learn2Work[6]) or sales conversations (Simucoach[7]), or as a support for career entry (TechForce[8]). However, there are few examples of successful Serious Games in the field of schools or institutes of higher education. Although today more and more multimedia applications are being used in classrooms as support, most teachers go without the use of Serious Games. Encarnação stated in (Encarnação 2009), that Serious Games "*... lack the public acceptance of being generally a value-add*". In (Cuban 1986), Cuban states that "*teachers are the gatekeepers of instructional technology*". This means, teachers need to

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[1] www.**enercities**.eu/

[2] www.**globalconflicts**.eu/

[3] www.**americasarmy**.com/

[4] www.**re-mission**.net/

[5] www-de.**scoyo**.com/

[6] www.**learn2work**.de/

[7] www.**simucoach**.com/

[8] www.**techforce**.de/

accept the technology. Otherwise even the best Serious Game will never be used in classroom. One reason for the lack of acceptance may be the missing proof of the value-add of Serious Games in (higher) education. Teachers lack instruments to measure the learning success when using Serious Games. Moreover, in current Serious Games, teachers have insufficient control over a gaming sequence, especially when a whole class is involved in a game. A single teacher cannot oversee 20 to 30 pupils, each in front of their own computer, at the same time, recognizing if one pupil has problems or another one is inattentive. A Game Master approach can help to address this problem. Imagine if a teacher would be able to have an in-depth overview of a game session with all necessary parameters regarding the pupils at hand. Furthermore, the teacher could influence the game in a way such that he/she could adapt the difficulty ad hoc or give in-game advice.

Serious Games offer another very promising alternative to traditional ways of education. As mentioned above, there are military "games" which are used to train teams in a virtual environment and other games for training sales conversations. These games allow a cost-efficient education without the need of expensive material (e.g. military) or expensive workshops. There is a need in higher education for such applications, too. Students attending a Physical Education (PE) teacher education program rarely have an opportunity to apply and test their knowledge in class during their course of studies. The reason is that it would be a huge administrational effort to organize real sports classes just for training purposes of future teachers. For this scenario, a virtual environment in which the students can practice would be an excellent alternative.

In the HMWK-funded project "Serious Games in der Hochschule" (engl.: "Serious Games for Higher Education"), a Serious Game is being developed, in which students attending a PE teacher education program, can internalize the typical sport lesson procedure, learn how to treat pupils and practice different sport exercises. Additionally, the instructor is able to participate in the game either in form of a virtual character (the school director) or as a bodiless participant. Thus, the instructor can observe the players and evaluate their performance. Furthermore, he/she can take influence on the game (e.g. adjust difficulty parameters or trigger events). Using motion capture technology, the players are able to recognize and to correct detailed movement errors in the game. The project partners are the Hessian Telemedia Technology Competence Centre (httc), the TU Darmstadt (Institute for Sport Science), the Hochschule Darmstadt, and the University of Gießen. This paper is structured as follows: In Section 2, we outline related work, followed by a detailed description of the didactical and Game Mastering concept in Section 3. In Section 4 we will explain important details about the implementation. We conclude with an overview of future work in Section 5 and a brief summary in Section 6.

Related Work

Physical Education has a dual mission in the German school system (see Bräutigam 2009). Its task is on the one hand to teach and on the other hand to educate. This means that, besides the training of sensorimotor abilities and sport skills, PE has to educate the children in general. This includes e.g. social skills, solidarity and fairness. Physical Education should help develop knowledge, skills and attitudes. Therefore, a future PE teacher must learn how he/she can educate his/her pupils for the sport and through sport. But there are not enough opportunities to train this. This training could happen in a game.

Therefore, a future PE teacher must learn how he/she can educate his/her pupils for the sport and through sport. Until now there is no existing game for the subject Physical Education. Digital sports games usually appear as Exergames (Wii Sports, Move, Kinect, etc.) in which the player moves his body to control the avatar, or the player plays the athlete (FIFA, NHL, MADDEN, etc.). A Serious Game in which the player assumes the role of a PE teacher does not yet exist, although there are so many opportunities and possibilities for the combination of Serious Games and sports (see Wiemeyer, 2009).

Though it is now known that digital games are a good way to learn, and although a media literacy of students is requested, Serious and Digital Games are not part of the German curriculum. In general, the most Serious Games are designed for high school or elementary school. Only a few games exist for higher education and none is designed for the teacher education or the PE teacher education. Today however, there are no Serious Games existing which enable a human person to act as a Game Master. Yet there is an approach by (Aylett & Louchart 2007) who use a virtual Game Master as an AI for story directing in a story-based game. Moreover, (Peinado & Gervás 2004) use Game Mastering concepts to address the Narrative Paradox.

In (Gee 2003), Gee explains how well made games equip the player with game-relevant knowledge and encourages to apply these mechanisms to teach by using games. (Herz 2001) tells about the chances of Multiplayer Online Games for teaching. (Steinkühler 2004) addresses the question "How can learning of tomorrow profit from Massive Multiplayer Online Games" and gives examples of learning in state-of-the-art

online roleplay games. Various examples of Serious Games simulations exist like Simport (Warmerdam et al. 2006) or JDoc (Sliney & Murphey 2008). Those games try to simulate the area to be taught as realistic as possible, giving the player the opportunity to play "what-if" scenarios. This way they provide a learning-by-trying.

The field of Game Mastering is rooted in traditional pen&paper roleplay games. However, until today a lot of work has been done trying to adopt the concept of Game Mastering to digital games. (Tychsen et al. 2005) compared computer roleplay games with pen&paper roleplay games in technical matters. (Tychsen 2008) furthermore created a technical analysis of pen&paper roleplay games. (Mäkelä et al. 2005) developed an ontology for roleplay games.

To make a Serious Game a good learning game, challenge, flow, feedback, curiosity, execution of scripts and adaptivity are some of these points which should be taken into consideration (e.g., Hays 2005) and are listed below. It is important for the gameflow to support the immersion of the player. Therefore, all didactic methods used in the game should not be obvious to the player. Bopp (Bopp 2010) calls this approach *immersive didactics*. The player must have the feeling to meet the challenges on his/her own even though he/she is in a learning environment and the game is leading him/her.

Also fundamental to the game play will be the execution of certain "scripts" based on the script approach of Hawlitschek (Hawlitschek 2009). In such a script, the order of actions in a specific situation is linear and fixed. Scripts are more or less plots which facilitate to react in a structured way in a particular context. The players have to execute existing scripts sequentially and hierarchically, such as the correction script or the first aid script. Single scripts are gradually more complex and sophisticated at higher levels. The adaptivity of the game to learning styles and abilities of the players plays another decisive role. Individualized feedback facilitates learning compared to non-individualized feedback and improves attitude and immersion (see Kickmeier-Rust et al. 2008).

Concept

"Virtual Sports Instructor" is a 3D Serious Game in which the player takes on the role of a PE teacher, thus being able to practice a typical sports lesson. The game takes place in a gym, with a class of several virtual students. The player passes through the typical procedure of a sports lesson starting with welcoming the students, checking for correct sports dress, and explaining the content of the sports lesson. The player has to decide which pieces of sports equipment are necessary for the current exercise, how they should be set up and which student should be assigned to which station. During the lesson, the player has to observe the exercises, detect errors and correct them. Furthermore, the player has to know when a pupil is ready to advance to the next station. During the lesson, various incidents can occur just like in a real sports lesson, for example a pupil may have an accident or two pupils fight. The player then has to react to the situation.

The current overall class activity and mood are always visible to the player, so he/she can see if children are bored and tend to disturb the lesson. The game can be played alone in order to practice or as a multiplayer game, where a second player can act as the Game Master. This player can observe the game and adjust it or intervene at certain points in the game. Furthermore, other players (of the same course) can join the game as observers. Those players can watch the main player and discuss the player's decisions.

The narrative background is the following: The director of a model school is in a critical situation, he is desperately looking for a PE teacher substitute. The best and most dedicated PE teacher of his school has been seriously injured and is unable to conduct his sports lessons. The player of the game is asked to replace the missing teacher. Proven to be a good PE teacher, the player may, according to the game level, rise in his/her position. After the position of a substitute teacher, he/she can receive a temporary and later on a permanent contract. The ultimate goal is the appointment as a tenured German civil servant. To get from one level to another, the player receives teaching assignments, for instance, one gymnastic lesson intended to learn a back extension role (backward role to handstand). This teaching assignment has to be performed in an authentic sports lesson. For a successful work with the students the player gets score points. If the students are unhappy, bored or unmotivated the player will lose score points.

Didactical Concept

The game Virtual Sports Teacher combines theory and practice of learning and teaching in sport. It is

about PE didactics. The user learns in an autodidactic way, he/she equips him-/herself with knowledge of sports science, and learns how to teach sports to students. The player practices in a virtual environment the conveyance of skills by using different methods followed by contemplations. The didactic concept describes the situations in which the player must prove himself. In these situations, the teacher learns to apply scientific knowledge and teaching skills. The following describes how the game progresses, how the player gets his quests and which tasks the player has to solve.
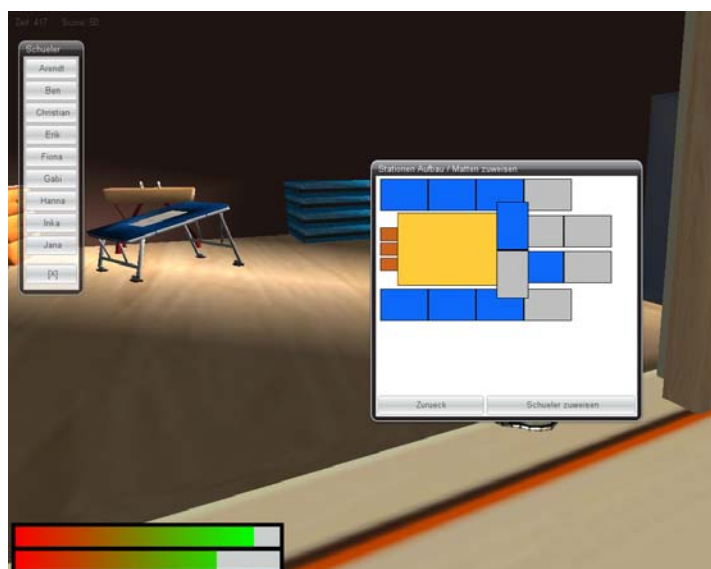

Figure 1: Screenshot of the player setting up the necessary pieces of sports equipment

Goal of the Player

The player, in the role of a PE teacher, has to perform in an authentic teaching-learning situation. In this context the player has to make decisions about core aspects of motor learning with appropriate respect to the situation and target groups. Within this process the player has to establish the integration of discipline-specific knowledge. With the aid of appropriate visual and verbal instructions, the player must recognize and analyze the movements of students and, if necessary, correct them. Besides the sports movements, the player analyzes situations, identifies problems and responds appropriately. Prior to the lesson, there are several organizational activities which have to be done by the player: structuring the lesson, selecting exercises and sort those exercises and teaching methods. What is the didactic goal of the game? What should the player learn by playing this game?

- How to structure and plan a sports lesson
- How to assemble the devices, which mats to choose and where to place them in order to avoid accidents (see Figure 1)
- Which methods and exercises to use to teach the students (e.g. the back extension role)
- What are the main errors of a certain movement (e.g. back extension role) and how to correct them
- How to motivate the students
- How to solve problems like arguments, fights, accidents, etc.

Design Features of the Game

The game offers an increasing level of difficulty, different learning contexts – meaning different sport disciplines – and takes learning preferences and gender issues into account. So it is planned to incorporate both the experimental moments of discovery for those who want to discover, and tutorial guidance for those who want to be guided. The multiplayer mode enables cooperative and communicative phases between the faculty

and the player, but also between individual players. Thus, the instructor/teaching assistant can pose questions and tasks which the player has to answer directly and solve, or the players can interact with each other to find alternative solutions. Further assistance and support opportunities, in addition to the instructor/teaching assistant (in the multiplayer mode), are integrated in the game´s digitized books, the Internet, Web Based Training (WBT) and e-learning modules like the hessian e-learning projects in sport science (e.g. biomechanics, functional analysis, cooperative Physical Education; see Wiemeyer & Hansen 2010). Overall, the game includes elements based on the three dominant approaches to learning, i.e., behaviorism, cognitivism, and constructivism (e.g., Kebritchi & Hirumi 2008; Egenfeldt-Nielsen 2005, 2006).

Sequence of a Lesson

During the game, the user must meet various teaching assignments. He/She finds his/her next teaching assignment in his/her field in the teacher's room. For example: physical education with a 5th grade (10 students, 5 male and 5 female). Lesson content: Development of the back extension role.

The player enters the gym. There, he/she must first analyze the given situation. He/She should get an overview of the gym and his/her students. For instance, are there any devices from his/her predecessor left in the room or where are the students located? The system enquires whether the player has screened the entire gym. It is important for the progress that a certain order of procedure is maintained. During the first part, the teacher has to convene and welcome his students. After this procedure, she/he has to check the presence of his/her students and make sure that the students brought appropriate workout clothes. If he/she does not so, there is a risk that a child gets injured.

The second part consists of the warm-up. The player must choose appropriate exercises according to the lesson´s goal and arrange them in proper order (exercises for general warming, stretching and coordinative practicing). After this he/she has to organize the structure and assemble the gymnastics apparatuses. The challenge is that all students must be equally involved in this process. If this is not considered, it will come to a dispute among the students. After the devices have been located, the mats have to be placed on the right position. If the player chooses too little mats or wrong mats, students could hurt themselves when they are practicing.

During the main part of the lesson, the teacher is more flexible in her/his approach and execution. He/She must assign the students into several exercise stations, according to their skill level. At each station, the player must choose the right helping or securing position. Her/his main task is to review gymnastic motions and to correct errors of his/her students. Doing this, the player must not lose sight of his/her pupils out of view. He/She must place him-/herself in a way that he/she can always see the most of the students. If the player is positioned inadequately, some students may start to scuffle.

Besides that, during class, disturbances occur and the player must cope with and solve them. Typical situations could be, for example, an argument or fight between some of the students or an accident caused by a defective device, as mentioned before. Coincidentally, the principal comes along (played by the course teacher) and poses difficult questions about the used teaching methods, biomechanics or first aid.

Towards the end of the lesson, the player must organize the strip of the devices, so that every student is involved in the process and finally say goodbye to his students.

Lesson preparation, organization and structure of the lesson and the actions of the teacher during the lesson will be evaluated, so that the player can obtain a detailed feedback

Game Mastering Concept

The idea of our Game Master concept is to provide the lecturer with a toolset to adjust, modify, and adapt the game at runtime in order to react to the player's performance. We want to enable the lecturer to have a comprehensive in-game overview over the player's performance and to be able to react if necessary. We can subdivide this problem into two components: The first question is how to provide the instructor with the necessary information, i.e. what parameters must be visible to the lecturer in order for him/her to be able to judge the game and learning situation correctly. The second question is how to provide the instructor with appropriate methods and tools to adjust the game according to his/her estimation of the situation.

In-game Assessment

The Game Master needs to know what the player is doing at every time. In other words, the Game Master has to be able to observe the player. For this purpose, we allow the Game Master to view the complete gym. The Game Master is not bound to an avatar, but instead he/she is bodiless and can oversee the whole scene. However, if desired, the Game Master can obtain the NPC avatar of the school director to actively take part in the game. Additionally, the Game Master needs a special interface providing information about the current state in the gym. That information is:

- The simulation/game time
- The overall mood and activity
- The state of each pupil
- All actions of the player

The simulation/game time is trivially displayed by a timer. The overall mood and activity bars are displayed in the same way as for the player. The state of a pupil includes information about the pupil's current activity, his/her current mood, and other static information, like character traits. All player actions are logged internally for an automatic evaluation of the player's performance. The Game Master is able to view the logged actions in-game. So, in addition to the visual feedback which the game master receives simply by watching the game, he/she also has a detailed list of player actions and a judgment made by the game about the correctness of the action.

In-game Reaction

In addition to the need for assessment, the Game Master also needs to be able to react to the player's actions. Therefore, we provide him/her with an integrated toolset enabling him/her to influence/adjust the game ad-hoc if necessary. The Game Master can trigger unexpected events, like a child having an accident, in order to increase the difficulty. On the other hand, he/she can prevent the game from triggering such actions automatically. Thereto, whenever the game would trigger such an event automatically according to the level of difficulty, it asks the Game Master for permission before actually triggering the event. When the virtual students are performing exercises, the Game Master is furthermore able to have them make exactly the errors he/she wants in order to focus on the errors he/she regards as important.

Just like in real class, the instructor will occasionally want to give tips or correct the learner if necessary. For this reason, the Game Master in "Virtual Sports Teacher" is not only a spectator who can trigger events, but he/she is also able to communicate directly with the player in form of an in-game chat. This chat field is separated from the chat with other students and highlighted in the GUI so that the player always notices when the instructor wants to communicate with him/her. Of course, the player himself can also ask for help at any time using this chat field.

In order to enable the Game Master to interact with the game in a more realistic and direct way, he/she can also take on an in-game role, the role of the school principal. If the Game Master chooses to do so, he/she plays the NPC of the school principal, illustrated by an own avatar in the game world. Being the principal, the Game Master has the same assessment and control options, but is illustrated as a real in-game person so he/she can actually "play" the role of the principal, giving special tasks to the player or inquiring knowledge in-game which improves the degree of realism.

Implementation

The idea for this game was to provide students attending a PE teacher education program with a tool to virtually train the curriculum of a sports lesson. Therefore, we created a 3D virtual environment. We decided to use the Unity3d[9] game engine to create the game because of the educational license model and the easy use. Moreover, we can import our own 3D-models in Unity3d and integrate own motion-capture animations for the

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[9] www.unity3d.de

sports exercises.

After starting the game, the player(s) can configure the game, i.e. decide about the sports scenario to play, the number of spectators, and the degree of difficulty. As soon as all players have joined, the actual game starts with the (virtual) teacher entering the 3D environment. The 3D environment is restricted to the teachers' room, the teacher's office, and the gym consisting of a main hall and an adjacent room containing the sports equipment.

The player's GUI contains an overview of the pupils, a bar displaying the total activity and the total mood. Furthermore, there are various buttons for interactions with the Game Master, for chatting and for game related actions. The player can talk to the pupils via a set of predefined statements or look at a self-made cheat sheet.

The gaming sequence is implemented as a Finite State Machine (FSM) as shown in Figure 2. There is a set of macro states with linear and fixed order (see Figure 2, left side) representing the fixed sequence of a typical sports lesson. In Figure 2 (right side), one of those macro states (*Welcome*) is shown in detail. It represents the first step of a sports lesson, entering: The teacher can choose between looking around in the gym, calling the pupils together, and saying 'hello'. This can be done in any possible order. It is even possible to skip some of these options. However, only one order is correct. In Figure 2 (right side), the FSM of the *Welcome* macro state is shown with all possible orders. Each circle contains the actions already performed and a number for the points received so far. The bold circles depict the correct path with the maximum number of 30 points if the player correctly first looks around, the calls the students together and finally says '*hello*'. For the sake of simplicity, we did not include the arrows from each circle towards the next macro state *Organisation*, which indicate that the player could decide to skip one or more action and proceed directly to the next step. Implementing the gaming sequence as an FSM, we are able to track the player's path through the game which is necessary in order to evaluate if certain tasks have been solved in the correct order (like the example above).
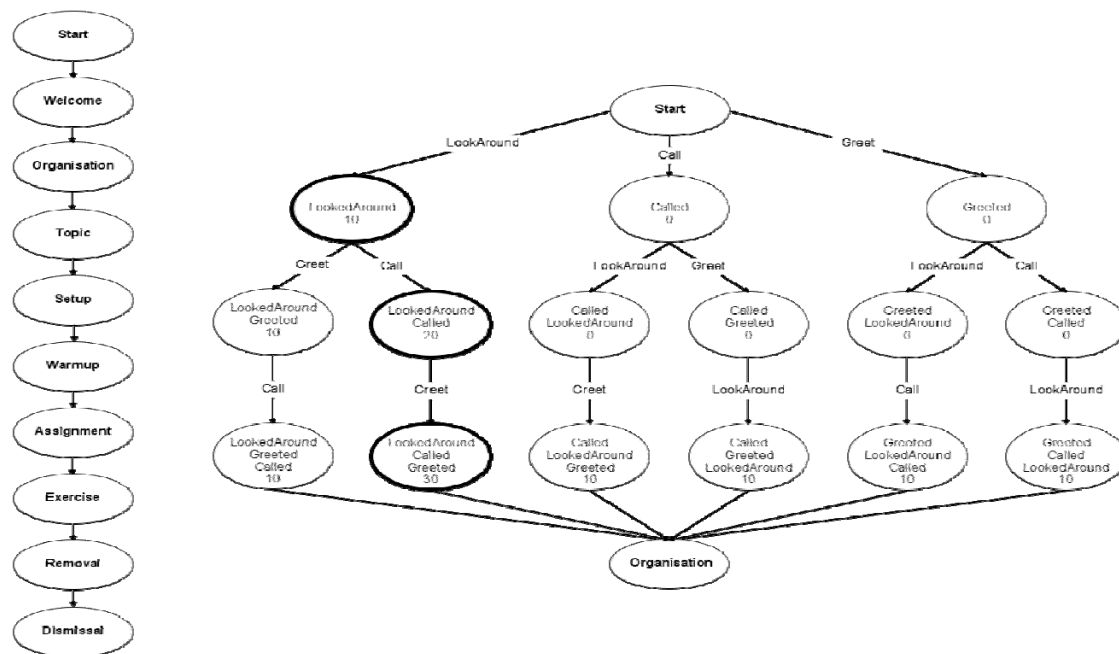

Figure 2: Diagram of the Finite State Machine of the *Welcome* state

Apart from learning the correct sequence of a sports lesson, the Virtual Sports Instructor player is also taught to choose and set up the correct sports devices and mats. The arrangement of devices and mats, however is different for each exercise. In order to have a flexible and extensible game with lots of different sport scenarios, we created an interface to the authoring tool StoryTec (Mehm et al. 2009), so that a subject matter expert is able to define own scenarios. Therefore, Virtual Sports Instructor is able to be parameterized by

loading an ICML[10]-file containing the necessary parameters for the desired scenario. Those are: The necessary stations, the number and configurations of the sports devices for each station, the configuration of the virtual pupils, and scenario-specific meta data.

Figure 3: Screenshot of the motion capture videos in the virtual world

Additionally, the player must learn to recognize typical errors concerning the exercises themselves and errors in assisting. Therefore, we included Motion Capture Animations from real sport students so that realistic movements can be displayed and errors be recognized from these movements (see Figure 3).

Virtual Sports Instructor is a multiplayer game. In addition to the player, the instructor (Game Master) can join the game as well as other students, thus being able to observe and comment the player's performance. So, each student and the Game Master can use their own PC and connect to the game via LAN or Internet.

Future Work

The next steps include the completion of the implementation of the game. As a next step, more content will be created like additional scenarios of sports exercises beyond the backward role to handstand and more motion capture videos. Furthermore, the level system will have to be finished. This means that the existing scenarios will have to be available in different graduations of difficulty. Finally, there will have to be an extensive evaluation of the game. We therefore plan to deploy the game in a real class of students attending a university PE teachers education program. The following parameters will be evaluated: effectiveness of learning, use/role of the game master, game experience, e.g., motivation / fun (e.g., Nacke, 2009), and replay-ability. For evaluation of the effectiveness of learning, we intend to prepare tests comparing traditional learning of the content to be taught in "Virtual Sports Instructor" and learning by use of the game. Also, the question has to be addressed, if the content to be taught is visible as such. The evaluation of the use/role of the Game Master will include comparisons of gaming sessions with and without a game master. The evaluation of game experience like motivation, fun, and replay-ability will be done by a qualitative player interview.

A major challenge is to integrate the various aspects of sports science into the game and to convey not only isolated aspects and knowledge, as it is usually handled in lectures, but to combine them. Therefore, it is important to analyze which setting is appropriate for the efficient application of games in the education of PE teachers.

Conclusion

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[10] ICML ist the XML-based data-format which is generated by StoryTec

In this paper we described a first approach for a new role of the instructor in a course for future physical education teachers. In "Virtual Sports Instructor", a player is able to virtually practice a physical education lesson. The player can practice the typical procedure of a physical education lesson, but can also learn about various physical education exercises, like e.g. the back extension role. In "Virtual Sports Instructor", we use 3D motion capture technology to include realistic movements of the various exercises, thus enabling the player to recognize and to correct movement errors or assistance errors. In "Virtual Sports Instructor", the lecturer can participate in the game in form of a virtual character or bodiless in the role of a Game Master. Thus, we enable the lecturer to observe and influence the game at runtime, providing the necessary information about player behavior and player performance and also providing tools for taking influence on the game at runtime. The game is being developed as a part of the HMWK-funded project "Serious Games für die Hochschule" and will be finished in November 2011. After the implementation is finished, we intend to evaluate the effectiveness of the Game Master concept by applying the game to a real class of students attending a PE teacher education program.

Acknowledgements

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