LEARNING SYSTEM BASED ON DIGITAL GAMES

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ABSTRACT

In today's educational system, the use of computers, distance learning and mobile learning are more present than ever, and in recent years intensive work is done in the application of digital games as a pedagogical tool. The vast and rich virtual worlds in the digital games are exactly what make them a powerful source for getting new knowledge. They give the participants an opportunity for understanding of the learning material by experiencing it. Studies have shown that people learn best from their practice, especially when part of a larger community whose members share common goals and work together to achieve those goals. Such games, from a pedagogical point of view, enable constructivist building of knowledge and offer opportunities for making connections between the current and the new knowledge. Therefore, the purpose of this paper is studying the existing learning systems based on digital games in order to build a new system whose main objective is to familiarize participants with the rules of study and the material taught within the Faculty of Electrical Engineering and Information Technologies. For the purposes of implementing this system, a virtual model of the faculty will be developed that, in addition to this purpose, can be used for other purposes.

I. INTRODUCTION

The technology changes the human society. It changes the way people live, their habits and their way of thinking. For many born in the 20s and 30s of the 20th century, radio and the telephone are technology. For many born in the 40s and 50s of the 20th century, television is technology. For many born in the 60s and 70s of the 20th century, computers and cell phones are technology. For many born in the 80s of the 20th century and beyond, computer games, the Internet, iPods, iPhones etc. are technology. This includes texting, blogging, wikis, open-sourcing, RSS preferences, alternate reality gaming, Facebook, MySpace, Youtube... [1].

Studies of the National Institute of Mental Health in the United States of America have shown that the brain structure in modern children undergoes new grey matter growth just before or around puberty. As a result of that, they have a higher IQ than previous generations. Studies have also shown that it is due to the use of new means of transmission of information and new means of interaction, which inevitably leads to a change in the way they think. Thus, the members of the modern generation, unlike the members of previous generations, are capable of quickly adapting to new conditions and recognition of new patterns, which allows better use of the situation in which they are located. Therefore, it can be concluded that computers greatly change the way people acquire new knowledge. The largest contribution to it is due to the use of digital games that allow the creation of new and better ways of learning in educational institutions, various social communities and workplaces, within today's Information Age. Digital games allow the creation of new social and cultural worlds that help people gain new knowledge through the exchange of thought, social interaction and technology, while doing what they want [2].

II. DIGITAL GAME-BASED LEARNING

The first step towards understanding how the digital games can transform education is changing the widely shared perspective that digital games are “mere entertainment.” More than a multi-billion dollar industry, more than a compelling toy for both children and adults, more than a route to computer literacy, digital games are important because they let people participate in new worlds. They let players think, talk, and act - they let players inhabit - roles otherwise inaccessible to them. These rich virtual worlds are what make games such powerful contexts for learning. In game worlds, learning no longer means confronting words and symbols separated from the things those words and symbols are about in the first place. The inverse square law of gravity is no longer something understood solely through an equation; students can gain virtual experience walking on worlds with smaller mass than the Earth, or plan manned space flights that require understanding the changing effects of gravitational forces in different parts of the solar system. In virtual worlds, learners experience the concrete realities that words and symbols describe. Through such experiences, across multiple contexts, learners can understand complex concepts without losing the connection between abstract ideas and the real problems they can be used to solve. In other words, the virtual worlds of games are powerful because they make it possible to develop situated understanding.

Although the stereotype of the gamer is a lone teenager seated in front of a computer, game play is also a thoroughly social phenomenon. The clearest examples are massively multiplayer online games: games where thousands of players are simultaneously online at any given time, participating in virtual worlds with their own economies, political systems, and cultures. But careful study shows that most games—from console action games to PC strategy games—have robust game playing communities. Whereas schools largely sequester students from one another and from the outside world, games bring players together, competitively and cooperatively, into the virtual world of the game and the social community of game players. In schools, students largely work alone with school-sanctioned materials; avid gamers seek out news sites, read and write FAQs, participate in discussion forums, and most importantly, become critical consumers of information. Classroom work rarely has an impact outside of the classroom; its only real audience is the teacher. Game players, in contrast, develop reputations in online communities, cultivate audiences as writers through discussion forums, and occasionally even take up careers as professional gamers, traders of online commodities, or game modders and designers. If we look at the development of game communities, we see that part of the power of games for learning is the way they develop shared values. The virtual worlds of games are powerful, in other words, because playing games means developing a set of effective social practices. They are rich contexts for learning because they make it possible for players to experiment with new and powerful identities.

In other words, by creating virtual worlds, games integrate knowing and doing. But not just knowing and doing. Games bring together ways of knowing, ways of doing, ways of being, and ways of caring: the situated understandings, effective social practices, powerful identities, and shared values that make someone an expert. Therefore, the next challenge for game and school designers alike is to understand how to shape learning in terms of games, and how to integrate games and game-based learning environments into the educational system [3].

III. LEARNING SYSTEMS BASED ON DIGITAL GAMES

As we saw previously, today's digital games represent a challenge for many people. Their potential to improve the way people acquire new knowledge is enormous, so many systems are designed for development of educational digital games. According to recent research in cognitive science [4], every successful learning system based on digital games should have the following features:

- Clear learning goals.
- Broad experiences and practice opportunities that continue to challenge the learner and reinforce expertise.
- Continuous monitoring of progress, and use of this information to diagnose performance and adjust instruction to learner level of mastery.
- Encouragement of inquiry and questions, and response with answers, which are appropriate to the learner and context.
- Contextual Bridging.
- Time on Task.
- Motivation and Strong Goal Orientation.
- Scaffolding.
- Personalization.
- Infinite Patience.

Therefore, the main goal of these systems is producing games that are used for:

- Teaching Higher Order Skills.
- Practical Skills Training.
- Creating High Performance Situations.
- Teaching Rarely Used Skills.
- Developing Expertise.
- Team Building.

The purpose of this paper is designing a learning system that implements much of the above mentioned features that the today's learning systems have. The system is called “Faculty of Electrical Engineering and Information Technologies”, and is a tool for computer-supported learning with basic intent to elevate the learning process at a higher level by applying the major educational capabilities of digital games. It is intended for everyone and its goal is to acquaint its participants with the epistemic frame of the students at the Faculty of Electrical Engineering and Information Technology. In it, they will have the opportunity to participate in a virtual environment that is a vivid representation of the faculty's premises and, therefore, get familiar with the location of some of the areas in it. Most importantly, they will also have the opportunity to get familiar with some of the material taught at the faculty, passing through examination and review the results from it. It provides the means to make the organizational chart of the faculty, and the material taught in it, more vivid and understandable not only for its current and future students, but for any other participant in the system. At the same time, the participants are not passive consumers of information, but actively acquire new knowledge based on their experiences within the system.

The system “Faculty of Electrical Engineering and Information Technologies” is intended for use in the process of independent learning and enables people to gain new knowledge at any place and at any time without a teacher. It is also suitable for distance learning.

IV. SYSTEM DESIGN

Designing the system's structure is one of the most important stages in the development of the system “Faculty of Electrical Engineering and Information Technologies”. It is built by using the Unreal Development Kit (framework that is widely used for creating digital games, advanced visualizations and 3D simulations that are powered by Unreal Engine 3), the Autodesk Maya (software that is used for 3D modelling and animation) and the Scaleform Gfx (framework that is used in order to integrate Adobe Flash and Unreal Engine 3 applications). Also, the new ICT techniques and improvements in the field of 3D graphics, enable the creation of effective system that highly attracts attention, and at the same time facilitate the learning process. Traditional learning and teaching supplemented with new educational software gives results that encourage their implementation, creation and further development [5].

The presentation of the structure of the system “Faculty of Electrical Engineering and Information Technologies” is accompanied with semantic network of frames and relations between them i.e. block diagrams with blocks, frames and relations between them. Two types of frames are used: frames for presentation of the basic concepts of the basis of knowledge and frames for presentation of multimedia elements. Semantic network is used for presentation of the structure of the basis of knowledge and the block diagrams for presentation of the structure of the rest of the modules.

The system “Faculty of Electrical Engineering and Information Technologies” is a modular system (Fig. 1.). Modules are dimensioned to follow the rules for designing this kind of computer supported education systems [6].

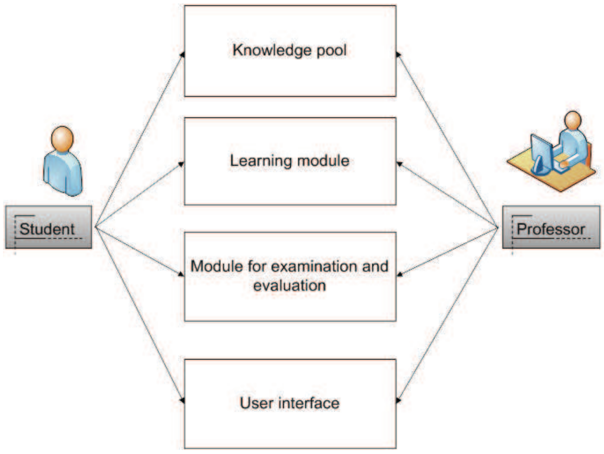

Figure 1: A modular structure of the system "Faculty of Electrical Engineering and Information Technologies"

A. *Knowledge pool*

The knowledge pool is one of the most important modules in the system "Faculty of Electrical Engineering and Information Technologies". The basis of this module is in fact the knowledge that the students and the educator use to communicate during the process of learning. The basic particle of the knowledge pool is the so-called basic concept of knowledge. The basic concepts are connected between each other with corresponding relations and together they represent the base as a whole.

The knowledge pool is semantically structured and can be divided logically to smaller parts that we call concepts. A concept is basic part of knowledge of a given base i.e. it is (smaller or bigger) part of the total knowledge stored in the pool (ex. coordinates of the location where the Archive is located at the Faculty of Electrical Engineering and Information Technologies, the principles of Risk Management, the principles of successful Software Testing...). The total number of concepts depends on the given pool of knowledge and from the chosen knowledge. We can introduce the knowledge pool with a help of bigger number of simple concepts or with a smaller number of more complex concepts. That means that the knowledge pool is infinite set (1).

$$C = \{c_1, c_2, c_3, \ldots, c_n\}. \qquad (1)$$

Each of this set represents individual concept. The number of elements of the set C represents the number of concepts in the pool of knowledge. The concepts are not mutually independent. That's why we can easily introduce a relation of strict subordination between them that represent the dependency between the learning of the first and the knowledge of the other concept. We call this relation preconditioned relation and we mark with → (Fig. 2.). For each two concepts c_i and c_j are in preconditioned relation $c_i \rightarrow c_j$, if the concept c_i is in front of c_j, i.e. for understanding c_j you need to understand c_i. We say that the concept c_i is precondition concept to the concept c_j. It is obvious that the concept cannot alone be precondition to itself, the same as the fact that two concepts cannot be mutual preconditions i.e. if the first concept is a precondition to the second it cannot be vice versa.

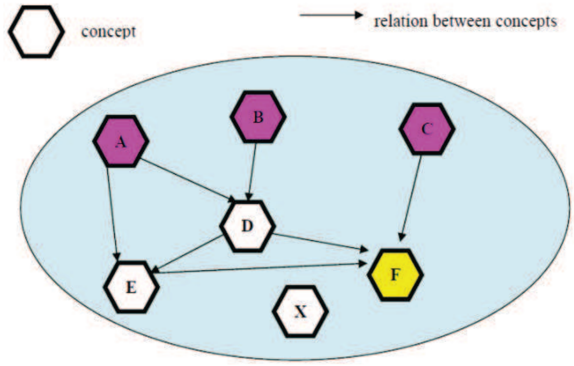

Figure 2: Conceptual graph of the knowledge pool.

The preconditioned relation is anti-reflexive, anti-symmetric and transitive because of the following characteristics:

$$c_i \in C: c_i \not\rightarrow c_i\,, \qquad (2)$$

$$c_i, c_j \in C: c_i \rightarrow c_j \Rightarrow c_j \not\rightarrow c_i\,, \qquad (3)$$

$$c_i, c_j, c_k \in C: (c_i \rightarrow c_j) \wedge (c_j \rightarrow c_k) \Rightarrow c_i \rightarrow c_k\,. \qquad (4)$$

According to the mutual dependency, the concepts of knowledge are divided in three groups: initial, final and middle. In the first group the concepts have no preconditions. We call these initial concepts. The second group is consisted of concepts that aren't a precondition. This group is a group of so called final concepts. In the third group are the remaining concepts i.e. concepts which have preconditions and at the same time are precondition to other concepts. Because of their characteristics, we call these concepts middle concepts. The final concepts represent the aim of the study. In order to fulfill the aim of the study and to learn the final concepts, the student has to learn all the initial and middle concepts, and afterwards all the final concepts learning the contents of the knowledge pool in that way. On Fig. 2, A, B and C are initial concepts, E and D are middle concepts, and F is final concept.

The system "Faculty of Electrical Engineering and Information Technologies" belongs to a group of specialized educational systems that cover a specific area of knowledge, because it covers the learning of the environment of the Faculty of Electrical Engineering and Information Technologies, and the material taught at it. During the creation of the knowledge pool it is very important to give examples, exercises, explanations and ways of implementing the curriculum that are very similar to the environment and process of education that take place within the Faculty of Electrical Engineering and Information Technologies.

B. *Learning module*

The Learning module is a part of the educational system "Faculty of Electrical Engineering and Information Technologies" that serves as a tool for executing the process of learning and teaching. This module has got double assignments: to help the professor bring out the curriculum during the process of teaching and to help the student in the process of self-study.

In order for the user to be able to access the requested concept and understand its content, the concept must be represented adequately in the three-dimensional virtual space. This is accomplished in the system in a way that each basic concept is described by one indicator (object) or a set of multiple indicators (objects). As the conceptual graph of the knowledge pool represents its structure through its nodes and the relations between them, the indicators in the three-dimensional virtual space represent the nodes and connections between them (Fig. 3). The nodes symbolize the indicators in the area, and connections - the relations that exist between them.

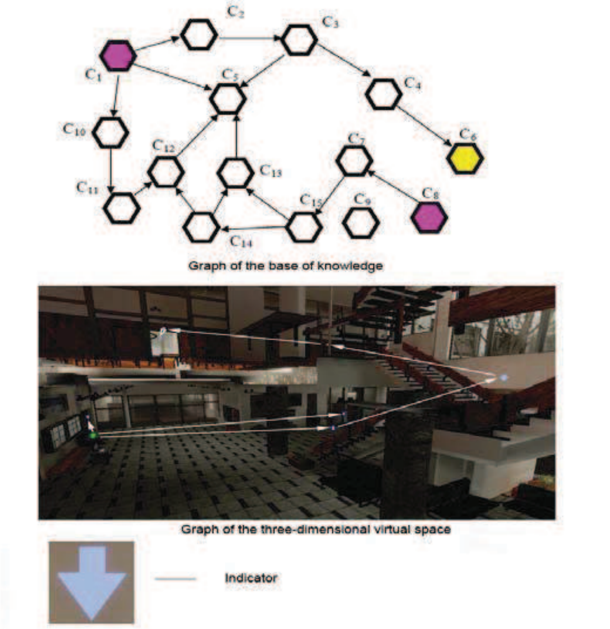

Figure 3: Graph of the base of knowledge, Graph of the three-dimensional virtual space.

The indicators represent objects in the three-dimensional virtual space that mark the area of the faculty that they are semantically related with. These indicators allow the concepts to be presented in a rich, entertaining and vivid manner. Namely, they navigate the students in the process of learning of the environment of the Faculty of Electrical Engineering and Information Technologies. Each indicator is conceptually linked to the specific segment of the faculty's environment that should be explored by the student.

The exploration of the environment is done incrementally, and the student can discover new parts of it only if he has investigated those segments that are currently set as a goal of the exploration. This allows constructivist knowledge building among students, because learning is an active process in which students learn new segments of knowledge (construct new ideas or concepts) based on their current and past knowledge - learned concepts (explored segments). The student selects and transforms information, generates hypotheses and makes conclusions based on a cognitive structure. The cognitive structure (schema, mental model) provides opportunities for acquiring experience and allows the student to exceed the frame of the gained information. Students are active agents that insert new knowledge in their cognitive schema (mental model). The process of learning occurs through the creation of knowledge in the cognitive schema. Moreover, students are given a certain degree of autonomy - the opportunity, through independent learning, to acquire knowledge about new concepts that are discreetly placed on a certain distance from one another. This allows the student to gain knowledge about (explore) new concepts (indicators) through understanding (research) of already known concepts (indicators), and, while in service of learning (research), to use his curiosity and desire to acquire new knowledge. In addition to this, the following techniques are used:

- Technique of direct leading which directs the process of learning through usage of indicators in a virtual three-dimensional space.
- Technique of adapting the annotation of the relations through usage of menus.
- Technique of adapting by covering the relations during which, only the relations towards those units that are necessary for archiving the goals are uncovered, and the relations towards the other units are hidden.
- Hierarchical navigation through the use of actuators that are connected to the indicators in the area of exploration

The student's knowledge is a subset of the set of concepts in the knowledge pool. Therefore, the model that represents it is not static, but a dynamic category. This is a category that constantly changes with each testing.

The first step towards defining the properties of the student model is determining the values of the testing K. Its value is determined as a ratio between achieved and achievable points. This coefficient can vary between 0 and 1. The value of the coefficient K depends on the achieved points during the testing and it defines the function of learned material $f(K)$ according to the level of the coverage of the model in relation to the contents of the knowledge pool. It determines which prerequisite knowledge and skills the student has achieved.

The function of learned material in the system "Faculty of Electrical Engineering and Information Technologies" is a fuzzy function. Beside the numeric value, $f(K)$ gets a descriptive value as well. The descriptive value describes the condition with suitable concept, whether it is unfamiliar, less familiar, familiar, well known, very well known or learned by the student.

All information about the properties of the student model is stored in appropriate system variables.

C. *Module for examination and evaluation*

The module for examination and evaluation is a part of the system that is used to estimate the previous knowledge before the process of learning starts, the newly acquired knowledge during the process of learning, and finally, the acquired knowledge at the end of the process of learning of a particular topic.

Estimation of the student's knowledge is made with a multiple-choice test. It's a combination of questions that are answered by the student at particular time and in particular manner. The answers are valued, transformed into points and than a grade is given.

The following principles are respected while creating the tests: each test consists of 5 questions; there are 4 offered answers for each question and only one of them is correct; each correct answer to a question bears 1 point; each incorrect answer bears 0 points; the total amount of possible points is 5; each question must be answered; and each student can revise the unanswered and answered questions until the test is completed.

The evaluation of the results from the test is important part of the testing process. It must be objective. That is why there is a need to transform the evaluations into numeric grades. The system uses criteria standardization with fixed borders introduced before the testing. The main task during this process is to determine in which group the student belongs to, according to his knowledge. This mode of regulation is simple and stimulating for students.

During the evaluation process, the students have an opportunity to see their answers to the questions during the testing process, and the correct answers to them. Thus they can see which of the questions they answered correctly and which wrong. That makes transformation of their knowledge by learning from their mistakes. At the end of the evaluation process, based on the rules for standardization of evaluation, students receive an adequate assessment that shows how well they have mastered the curriculum.

D. *User interface*

Together with the module of learning this is the most important part of the system. It enables the whole communication between the user and the computer. The most important issue of user interface is that it enables interactive communication. Thanks to that, the students are not just passive listeners, but active participants in the virtual world that learn from their experience, solve problems, answer questions, and receive a feedback, which enables them to direct the flow, intensity and rhythm of the learning process.

Whole communication is done through the user interface. It is adjusted regarding the organizational structure of the Faculty of Electrical Engineering and Information Technologies and the learning material that is taught at it. Planning and designing the user interface is done in accordance with the standards and experience of designing educational digital games in the world. Therefore, during the phase of projecting and designing the users interface, the following principles are respected:

- The user interface is a graphical interface since this type of interface is very close to the interfaces used in the today's digital games.
- The user interface is objectively oriented towards the initiation of the following activity of the user, i.e. navigation of the user through the system. It outlines the objectives that need to be achieved and gives instructions that are necessary for their achievement.
- The user interface consists of various elements (fields for entering text, drop-down menus, labels for displaying text etc.), which help participants easily understand the material to be studied.
- The elements used in the user interface suggest concepts that are semantically related to them, i.e. they direct the process of learning and teaching.
- Every element of the user interface has a unique function through the whole educational system. This is done in order to associate its appearance to its functionality.
- The system uses mouse and keyboard for data input.
- The user interface consists of various instructions, questions and answers, menus and forms.

V. CONCLUSION

Drawing from the constructivist theory of education, digital game-based learning (DGBL) connects educational content with digital games and can be used in almost all subjects and skill levels. It provides learning opportunities that engage students in interactive instruction and helps prepare them to participate in the globalized, technological society of the 21st Century.

The level of user interaction that is present in the system "Faculty of Electrical Engineering and Information Technologies" is very similar to the level of interaction present in the modern educational digital games. In it, students are surrounded by a virtual environment and they have the opportunity to interact with it through the various forms of user interface, and learn from their experience. Therefore, the system achieves its main goals - to provide a fun and attractive way to motivate students to contribute and be interested in learning new things related to the environment of the Faculty of Electrical Engineering and Information Technologies and the material taught at it.

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