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An Approach to E-learning in the Virtual Education Space

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Abstract. The Virtual Physical Space (ViPS) was developed in the DeLC Laboratory at the University of Plovdiv in Bulgaria as a reference infrastructure for supporting different CPSS[1]-like applications. The main challenge to be taken into account is the integration of the virtual and the physical worlds in both directions – from the physical world to the virtual and vice versa. The first bottom-up direction addresses the virtualization of physical objects ("things"). The top-down direction aims to "locate" the system intelligence as close as possible to the physical world. At the same time, special attention is paid to the support of various groups of users. The Virtual Education Space (VES) is an adaptation of ViPS for education. In this paper, the VES e-learning environment is presented. VES provides a reference architecture, which can be adapted for various forms of education supported by information and communication technologies. Furthermore, we recognize that the learning process takes place in an environment that integrates the virtual and the physical worlds. E-learning in the space is demonstrated by means of examples from school education.

Keywords: E-Learning, Virtual Education Space, Intelligent Agents, Game-Based Learning.

1 Introduction

In recent decades, the use of Information and Communication Technologies (ICT) in education has been the subject of growing theoretical and practical interest. A significant number of well-known software companies offer various tools for ICT-supported education. Many universities also develop and implement their own projects. Usually, the capabilities of the currently used systems are greatly overestimated. At the same time, basic aspects of education such as the methodology, pedagogy, and psychology are underestimated or even partially or completely ignored. A certain justification could be that for these aspects to be realized, it is extremely difficult (at least for now)

[1] CPSS- Cyber-Physical-Social System [3]

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to create appropriate and formal models powerful enough to become the required theoretical framework for the supporting software. Taking this situation into consideration, various specifications have been developed (e.g. SCORM, QTI), which encourage the integration of methodological and pedagogical models into education environments.

Nowadays, lots of different statements about ICT-enhanced education can be found in the specialized literature, some of which are quite extreme, e.g. that e-learning can replace face-to-face education. The authors, however, are firmly convinced that face-to-face education has no effective alternative. Computer systems in education should only be considered as supporting didactic technologies. The challenge is to create them as effective support tools. It is hardly possible to develop a universal tool to cover all aspects of the educational process. In our opinion, the way to achieve this is through specialization and personalization of the supporting tools. In this sense, clear and unambiguous definition and classification of the huge variety of educational approaches is extremely important.

In this article, we will introduce an e-learning environment known as VES (Virtual Education Space). The above considerations are embodied in the construction of VES. This space was not created all at once – our team has been working on its implementation for years as each subsequent version of the environment builds on the previous one. We initially implemented an environment called DeLC (Distributed eLearning Center) to support blended and independent learning at the Faculty of Mathematics and Informatics at the University of Plovdiv. DeLC functions as a network consisting of individual nodes known as eLearning Nodes. Nodes are real training systems of laboratories, departments, faculties, colleges, schools, and universities that offer a full or partial cycle of training. Each eLearning Node is a stand-alone host of a set of electronic services [1]. Despite the fact that DeLC was a successful project, we identified as an inconvenience that it does not take into account the physical environment, in which the learning process takes place. Building an infrastructure in which the virtual world is naturally integrated into the physical environment would open up new opportunities for providing educational services and learning content in a personalized and context-oriented way. Students with disabilities in particular would benefit from such integration.

Consequently, in the following period, we started working on the creation of ViPS (Virtual Physical Space), embodying the ideas of CPSS (Cyber-Physical-Social System) [2] and IoT (Internet of Things) [3]. ViPS is a reference infrastructure to support the development of CPSS-like applications [4]. The main challenge to consider is the integration of the virtual and the physical worlds in both directions – from the physical world to the virtual and vice versa. The first bottom-up direction focuses on the virtualization of physical objects ("things"). The top-down direction aims to "locate" system intelligence as close to the physical world as possible. At the same time, special attention is paid to the support of different user groups.

As a reference architecture, ViPS is domain-neutral; it has to be adapted to the desired domain. Subsequently, we faced the opposite challenge, i.e., in which way to adapt ViPS for education.

The rest of the paper is organized as follows: a short review of VES is considered in Section 2, Section 3 presents selected applications operating in the VES, and finally, Section 4 concludes the paper.

2 VES in a Nutshell

The Virtual Education Space is the ecosystem of the Internet of Things. The essential aspects of VES are the following:

- Users are the focus of attention;
- Physical “things” are virtualized;
- There is integration between the virtual and the physical worlds.

The VES architecture reflects and presents an identical model of the real physical world in the digital world. Since VES is essentially a CPSS environment, the user is placed in the center of the space through his/her personal assistant (PA). VES provides virtualization of real objects. Modeling "things" that provide a link between the physical world and the digital world of the Internet requires that factors such as events, time, space, and location be taken into account.

Agent-oriented approaches are particularly suited to building CPSS applications. The main components of VES are assistants, implemented as rational BDI agents, which consist of two main components:

- Deliberation — as a process, by which an agent forms its current goal or objectives.
- Means-Ends Reasoning, which prepares a plan for the achievement of the established goal.

By itself, the agent has proactive, context-sensitive, and intelligent behavior, but it is not suitable for providing business functionality. Services are a good solution for providing functionality, but they are static and inactive. Therefore, agents have to include appropriate interfaces to services in their internal architecture. In this way, VES functions as an ecosystem open to expanding and upgrading with new services.

The creation and implementation of various educational services require the definition of the basic characteristics, opportunities, advantages, differences, and problems between the different forms of education. Our research is based on a specific classification model, which we will present below.

In many cases, the notion of “e-learning” is used to mean any type of education supported by Information and Communication Technologies (ICT). However, the education process is multi-aspect and multilayered. Thus, more precise definitions of the term ‘e-learning’ are needed to develop effective education systems. A successful education environment has to combine methodological, pedagogical, and psychological approaches with structuring and a suitable presentation of the domain knowledge. To develop effective education environments, it is necessary to distinguish at least three explicit models – pedagogical, domain knowledge, and a learners’ model.

Distinguishing the different forms of e-learning is fundamental to the development of VES. In the space, the above-mentioned models are the basis for developing tailor-made systems for different types of education (Figure 1.). Furthermore, we recognize that the learning process takes place in an environment that integrates the virtual and the physical worlds.

Personalization is a basic characteristic of training in every CPSS, as the effectiveness of training is directly dependent on the degree of adaptation of the offered knowledge and teaching methodology in accordance with the personal cognitive and emotional characteristics of the learners. If we try to graphically represent the different forms of learning in this aspect, we can consider a coordinate system with two axes: X – personalization of the learning content, and Y – adaptability and personalization of the learning process. The change along the X axis is from general learning content for all students to specific learning materials adapted to the individual student. On the Y axis, the change varies from a predetermined learning process to an adaptive, dynamically changing learning process according to the specific personal characteristics of the individual student. The various existing forms of education can find their place in this coordinate system.

Classical Training provides real communication between the educator and the learner in the physical world as the “educator-learner” relationship has a cardinality “One-To-Many”. In CBT, we can look at two types of educator-learner relationships: "One-To-Group" and "One-To-Personas." The first of them is based on building a stereotypical hierarchy of students according to their type, curriculum, level of basic knowledge, etc. (e.g. second-year students of Informatics, full-time education), while in the second each learner joins a certain Person [5] that is closest to his/her personal characteristics.

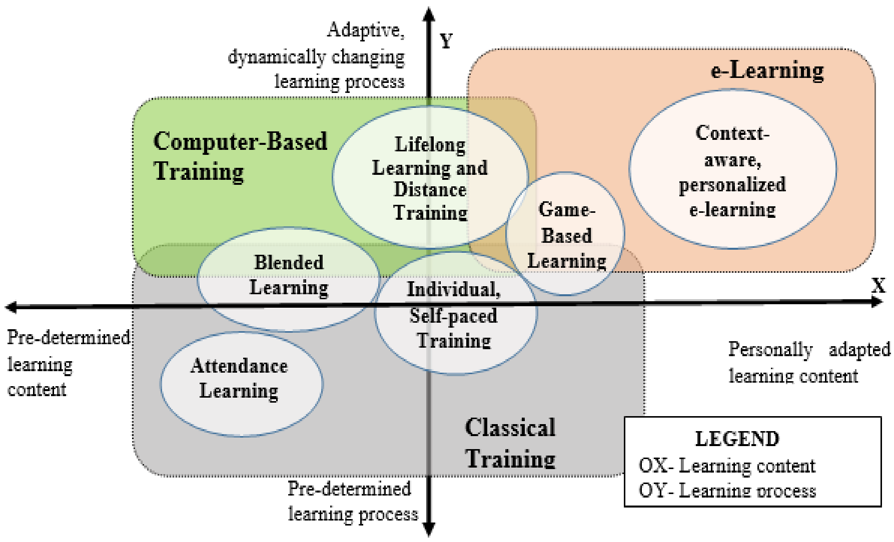

Fig. 1. Classification of the different forms of education

E-learning can be seen as a qualitatively new learning process, unlimited in terms of time and place, which provides individualization of the learning process and provides appropriate learning resources from any place and at any time at the request of the particular learner as a result of perceived necessity [6]. According to the concept of VES as a CPSS multi-agent system, all participants in the learning process interact through their personal assistants (PA).

The Cyber-physical-social space is a fusion of cyberspace, the physical, and the social space. In CPSS, not only the behavior of the individual user can be processed in cyberspace, but also social interactions in the physical world (ex. specific services for disabled students). In addition, in CPSS, the status, interests, and knowledge of users are developed in the process of social interaction based on defined operations, communications, and services [7]. VES as a CPSS space (Figure 2) provides the ability to receive a "One-to-One-in-CPSS" relationships.

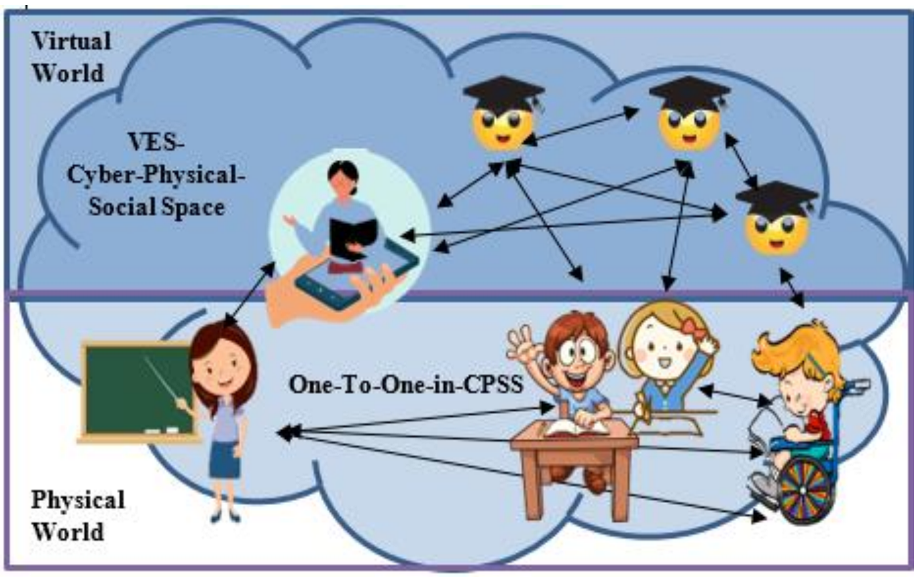

Fig. 2. “Educator-Learner” Relationships in the VES e-Learning Space

Teachers and learners interact in this space personally or through their personal agents (PAs that are constantly self-learning, reflecting, and serving the specific goals, interests, and desires of trainers and learners). The learning content and the learning process are dynamically adapted to the knowledge and specific characteristics of the individual students.

3 VES Applications

According to the differentiated and personalized approach presented above, the space is ViPS's adaptation to support various kinds of e-learning. The applications running in the space are mainly implemented for two user groups: university students and pupils. Furthermore, the tools can be adapted and customized for disabled learners. At university, VES is used to conduct blended, self-paced, and lifelong learning; for school – individual and game-based education, respectively. The kernel of self-paced learning is a SCORM 2004 Engine. One of the benefits of the SCORM 2004 [8] content is that teachers can follow student progress in real time. The blended learning environment includes modules such as a test engine (QTI 2.1 [9] compatible), a student's personal assistant (called LISSA), a student's book and a teacher's notebook. Two school applications are briefly presented to demonstrate education in the space.

The first application, known as BLISS, is an adaptation of the reference architecture of ViPS to support the learning process in high school [10]. The system is designed to work with students in an independent and mixed form of secondary education. BLISS (Figure 3) is implemented as a multi-agent system and includes two basic components.

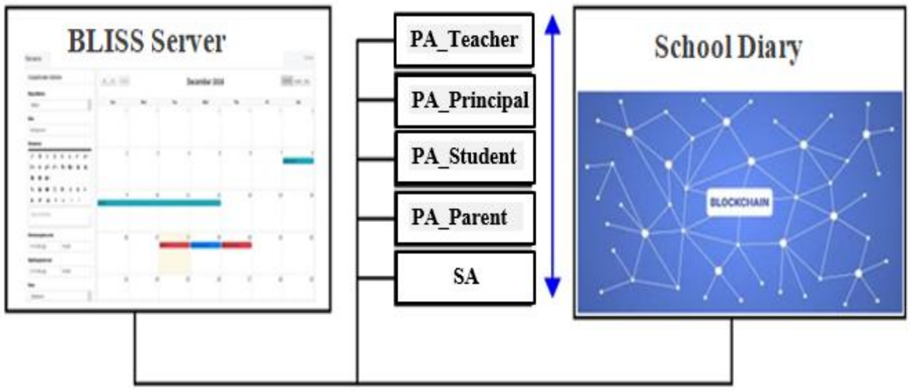

Fig. 3. BLISS architecture

The first component of the space is the BLISS server, and the second one is a school diary, implemented by using block chain technology. Different types of assistants interact in their space, the purpose of which is to deliver the appropriate educational resources and services to the users – students, teachers, parents, the principal, and the school administration.

- PA_Student. This PA, assisting students to fulfil their daily duties in accordance with the established curriculum, informs about all upcoming events that concern it such as exams, lessons, training sessions, consultations, and others. It monitors and reminds the student what they need to prepare before the upcoming event. The PA is able to prepare analyses of the results of the student's participation in the learning process. Figure 4 presents the interface for mobile devices of the developed prototype PAStudent.

- PATeacher. This assistant is intended for teachers. As in the case of the PAStudent, it can also remind of upcoming events and the necessary preparation. Its main function, however, is to assist teachers to track and analyze the participation, outcomes, and progress of their students' learning process.
- PAPrincipal. The purpose of this assistant is to facilitate the school principal to effectively manage the school institution. The assistant is primarily intended to help in the planning, conducting, and controlling the learning process.
- PAParent. The aim of this assistant is to provide information to parents about the progress of their child at school. The parent can see information about the student assessments, the events that their child has to attend, and the grades assigned by the teachers.

In the BLISS Server, all information objects (such as lessons, exams, consultation, self-preparation, meetings, schedules, etc.) are presented as Domain-specific events. Authorized teachers can create, update, and remove events through their personal assistants. The server stores these events, controls the access to them, and provides them to students to generate, manage, and control customized curricula and schedules. Any change to the server is automatically perceived by all the "interested" assistants.

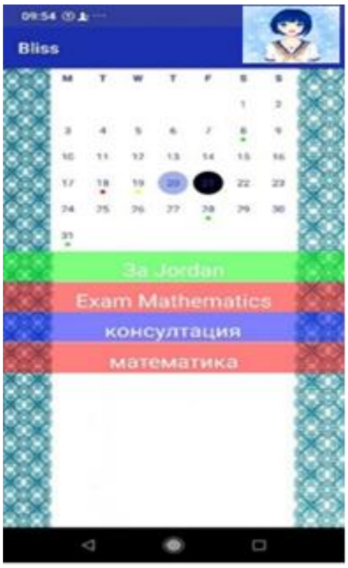

Fig. 4. The PA_Student visual interface

By developing the e-school diary, we aim to record change-sensitive content (such as student assessments) by using a block-chain, and to manage a variety of services designed for different user groups. To use stored information, we employ an operational assistant (SA) that responds to the change in the block-chain environment of the electronic diary and informs all personal assistants that are affected by this change (for example, the student's parents or the class teacher). The first version of BLISS is designed to teach students in self-paced and lifelong learning. Now we are testing its implementation for full-time students who, given the realities of the global pandemic COVID-19, are being taught in different forms of distance and blended learning.

The second example is a game-based environment (Figure 5.) consisting of three components [11]. The Pupil Personal Assistant (PPA) guides and encourages players to progress in the educational games provided by voice and text messages. It builds an environment consisting of two parts: a game desk visible to the player and a game diary accessible only to the teacher. In fact, the game desk operates as a graphical interface, through which the game is conducted. The course of the game is recorded in the game diary. In this way, the behavior and success of the player can be analyzed later.

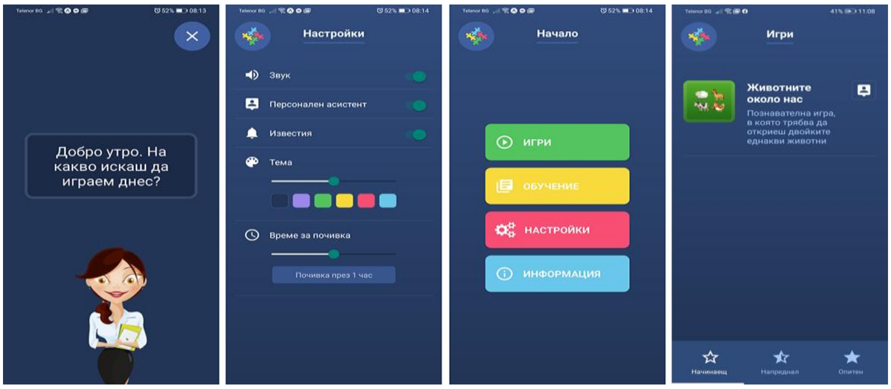

Fig. 5. Play and Learn – Personal assistant, Home screen, Settings screen, Games

The PPA selects the desired game from a game library. This library stores the program implementation of the game's business logic. Currently, the library contains education games for traffic rules and various games for students with specific educational needs and autistic children (Fig. 6.). The third component is an editor, with which players or teachers can create a virtual game desk close to the real world.

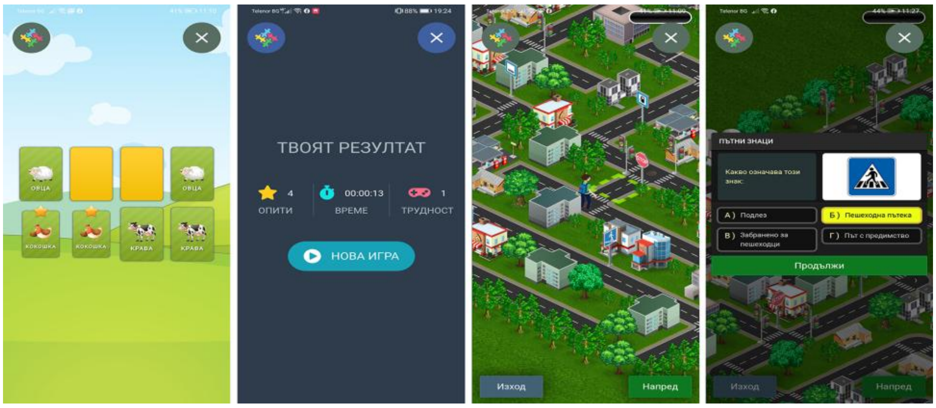

Fig. 6. Play and Learn – Games: "Animals around us" and "My village"

In many cases, the analogy with reality is essential. For example, when playing the traffic rules game, children first learn the traffic regulations in the neighborhood (settlement) where they live. Usually, a safe route from home to school is chosen for training in the first place. Web client and mobile client access are possible.

4 Conclusion

The applications running in VES were developed in different periods of time and their server parts are spread over different hardware configurations. Currently, a unified three-tier infrastructure is under construction, which will serve ViPS and its adaptations (including VES). The infrastructure consists of sensor networks on a low level, a cloud infrastructure on a high level and an intermediate communication network. We intent to relocate the VES applications so that all servers will be located in the cloud.

The use of the BLISS learning environment at school enables not only students, but also adults who for some reason have dropped out of school to continue to receive appropriate learning resources and services and to continue learning at a time and manner convenient for them.

Regarding game-based learning, we intend to expand the game library with new games. Both kinds of games were not chosen at random; studying the traffic rules is insufficient at school and the game for autistic children is an extremely important tool for their development, especially in the context of a global pandemic.

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