A SPECIAL PURPOSE E-LEARNING ENVIRONMENT: BACKGROUND, DESIGN AND EVALUATION

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ABSTRACT

This study presents the concept of Special Purpose E-Learning Environments (SPELEs). The main aim of these environments is to meet the learners' individual learning differences related to a specific learning subject. An architecture of the design of SPELEs is presented. The background of this design, which is based on interpretations of modern constructivist and social views of learning in the Internet context, is also presented. Based on this architecture a specific SPELE, designed to the learning of concepts related to Files and Peripheral Storage Devices (F.P.S.D.), is demonstrated and its pilot evaluation study with real students is reported. The analysis of the data verifies the theoretical design of SPELEs which consists of five parts: (A) organization of the content of a specific learning subject, (B) learning activities (C) learner activity space (D) learner assessment and (E) learner communication. The analysis of the data also gives evidence for future improvements of the specific SPELE mentioned above.

KEY WORDS: E-learning, Constructivism, Web-Course Development, Course Evaluation, Computer Science Education

INTRODUCTION

'General Purpose E-Learning Environments' (GPELEs) are designed to support the learning of all learning subjects. Some well known examples of GPELEs are: WebCT(www.webct.com), Learning Space (www.lotus.com/ home.nsf/welcome/learspace) και CENTRA-Symposium (www.Centra.com/products/ symposium) etc. A number of studies have shown the positive learning results achieved by learners in the context of these environments. Despite this fact, these environments do not provide the learners with opportunities to use specific tools and representation systems to support active and constructive participation for the learning of each specific subject. Moreover, GPELEs do not provide tools and representation systems that take into account specific research studies illuminating the learners individual differences regarding a specific subject. As a result, in the context of GPELEs, the learners' individual learning differences are not fully treated.

It is worth mentioning that, the learning process is closely related to each learning subject as well as to learners' individual learning differences. These differences are also firmly dependent on each learning subject, as it has been reported by the relevant scientific communities. Based on the above, the value of Special Purpose E-Learning Environments (SPELEs) designed for the learning of a specific group of concepts within a specific knowledge domain is obvious. Furthermore, the concept of SPELEs is well situated in the context of modern constructivist and social theories of learning, where the learning process is viewed as an active, subjective and constructive activity in a context rich in computer tools (von Glasersfeld, 1987; Vygotsky 1978; Noss & Hoyles, 1996).

In the context of these theories a new general architecture for the design of SPELEs has been constructed. This architecture emphasizes learning in a context supporting: a) the learning of essential aspects of each learning subject (von Glasersfeld, 1987), b) open real-life learning activities (Jonassen, 1991; CTGV, 1992; Jonassen, 2000; Liu & Hsiao, 2002), c) the learners' individual differences as they emerged from relevant research studies (Kordaki & Potari, 2002), d) content presentation in multiple hyper-linked representation systems organized by using the learning activity as the basic structure-unit (Jonassen, 2000), e) active learning using a variety of representation systems and computer tools (Kaput, 1994) as well as experimentation with representations and tools handling primary sources of data and using hands-on experience (www.ncrel.org/sdrs/areas/issues/content/cntareas/science/sc500.htm.),

f) multiple ways of assessment (von Glasersfeld, 1987) including the participation in appropriately designed games, g) appropriate intrinsic/and extrinsic feedback for self correction (Papert, 1980), h) multiple ways of communication (Harasim, Hiltz, Teles & Turoff, 1995), and i) real life operations and objects used as metaphor-representation systems of computer operations and objects acknowledged. It is worth mentioning that SPELEs based on such an architecture have yet not been reported.

The proposed architecture was used for the design of a SPELE for the learning of concepts related to Files and Peripheral Storage Devices (F.P.S.D.) for secondary level education students. These concepts are viewed as essential for elementary computer learning. Such an e-learning environment for the concepts mentioned above has also not yet been reported.

The chapter is organized as follows: In the following section the background of SPELEs is presented. Next, the proposed architecture for the general design of SPELEs is demonstrated. Then, the design and the pilot evaluation of the F.P.S.D. e-learning environment using real students is reported. Finally, the empirical results from this study are disscussed in relation to the specifications of the proposed architecture for the general design of SPELEs. The chapter ends with the conclusions.

BACKGROUND

The Internet has been recognized by a number of researchers as a medium that gives opportunities for the design of learning environments based on modern constructivist and social theories regarding knowledge construction (Harasim, 1989; Jonassen, Carr, & Yueh, 1998; Maureen, 2000; Hofstetter, 1998; James, 2000; Dillenbourg, Schneider and Synteta, 2002). Moreover, the fact that the Internet gives learners the chance to learn in their own time and place, contributes towards equal learning opportunities. In addition, the Internet provides schools with opportunities to exchange learning experiences, so they can acquire a new perspective and broaden their world to society (Harasim, Hiltz, Teles & Turoff, 1995). At the same time the communication capabilities (Computer Mediated Communication) provided by computer networks and especially by the Internet, expand and alter the learners' communication abilities (Harasim, 1990; Harasim, et all., 1995; Miranda & Pindo, 1996; Maureen, 2000).

E-learning environments can be mainly identified by the following features (Dillenbourg, et al., 2002):

- A designed information space
- A social space for educational interactions
- An explicit representation of the information/social space; this representation can vary from text to 3D immersive worlds
- A possibility for the learners to be not only active, but also actors: they co-construct the virtual space
- An integration of heterogeneous technologies and multiple pedagogical approaches
- Representation of physical environments

In the design of Internet based learning environments, the selection of appropriate learning theories has a potential impact. In fact, courseware effectiveness is bound to the pedagogical context of use: the pedagogical scenario in which the courseware is integrated, the degree of teacher involvement, the time frame, the technical infrastructure, and so forth (Dillenbourg, et al., 2002). Certain technological scenarios might lead to more centralised control or to higher shares of individualised learning as opposed to partner work. Such potential changes originating from the inherent logic of the technology without a clear pedagogical justification should not be accepted. The design of educational scenarios should in first place be based on pedagogical premises and objectives (Hoppe, 2002).

Traditional ‘behaviorist’ learning theories (Skinner, 1968) are usually implied in those e-learning environments which are dedicated to the learning of all learning subjects. These environments can be characterized as ‘General Purpose E-Learning Environments’ (GPELEs). The design of such environments mainly emphasizes the eye-catching presentation of the learning content in a variety of forms. Multimedia, hypermedia, sounds, animations graphics and bright colors are used. Usually, the content is organized sequentially, starting from the simplest topics of the learning subject and gradually moving to the more advanced ones. Furthermore, the proposed learning content usually does not stress the essential and basic concepts of a specific domain of knowledge but covers all its concepts irrespectively. The proposed learning activities are mainly in the form of ‘drill and practice’, that is, school-book like activities, while the motives given for learning are external and concern mainly the passing of tests. High level critical thinking is not cultivated by these kinds of activities whose solutions are usually standardized. Using such activities, the evaluation of learning is easy as it can be automatically performed by the computer. As a consequence, the learners’ assessment is mainly based on the results they produce when performing the given tasks. The use of communication is usually limited to explanations given to the learners by their teachers. In the case of the Internet it is mainly used for giving out the learning matter in the students’ own place, and no emphasis is given on ensuring rich communication between those involved in the learning process. Moreover, the learners’ individual learning differences are not respected as it is the authority of both the content and the teacher that is acknowledged. In the context of these environments, the learners usually accept a passive role as they have to spend much of their learning time in focusing on reading the provided book-like learning materials. On the whole, the learners’ interaction within such environments is limited to searching for information through the provided learning materials and in trying to perform recall-based learning activities.

Constructivist and social theories of learning are more suitable for the design of SPELEs. Designers of computer based learning environments are influenced by these theories (Papert, 1980; CTGV, 1991; Laborde & Strasser, 1990, Noss & Hoyles, 1996; Duffy, Lowyck & Jonassen, 1989). Constructivist learning theories emphasize the active, subjective and constructive character of knowledge, placing the learners at the centre of the learning process (von Glasersfeld, 1990). In addition, social theories of learning stress the importance of computer tools, and more specifically the significance of computer-based learning environments in the learning process (Noss & Hoyles, 1996; Crawford, 1996a; Crawford, 1996b). In contrast to traditional theories, modern theories of learning put emphasis on the essential and fundamental concepts that structure a specific domain of knowledge. Furthermore, modern constructivist and social theories of learning emphasize the role of a context, rich in appropriately designed tools, aiming for the performance of holistic, real-life, problem solving learning activities. These types of activities enable learners to develop a strong motivation so that they can be actively involved in their learning processes. Moreover, the performance of these activities puts the learners in the problem solvers' position by requiring a high level of critical thinking. In addition, these activities are designed to be solved in many ways, so that the learners' individual differences are acknowledged. In enabling learners' to express their individual differences regarding each specific learning subject, the role of multiple and linked representation systems are necessary (Dyfour - Janvier, Bednarz, & Belanger,1987; Kaput, 1994; Kordaki & Potari, 2002). Learners can construct their own solution strategies in handling the given tasks by selecting among the provided representation systems, those most appropriate for their own cognitive development.

A number of representation systems can be used in the context of the web, such as: tables, graphs, diagrams etc (Kaput, 1994). New representation systems have to be invented in order to meet the learners' individual needs. Among representation systems, the simulations of real life situations can be effectively used as metaphors to help learners in their understanding of learning subjects. By the use of multiple representation systems (MRS) it is possible for learners, to make a smooth transition from the real-world; with objects and activities of everyday life, to the computer-world; with computational objects and operations. Moreover, the use of multiple representations of variable cognitive transparency in the design of computer learning environments has been recognized as significant in the process of learning abstract concepts (Dyfour - Janvier, Bednarz, & Belanger,1987; Sutherland 1995; Kordaki & Potari, 2002) and more specifically in the process of learning concepts of Computer Science (Vlahogiannis, Kekatos, Miatidis, Misedakis, Kordaki & Houstis, 2001).

A number of e-learning environments has been designed taking into account modern theories of learning have been reported by the literature. Some of them emphasize the presentation of the learning content using Multiple Representation Systems (MRS) (Tretiacov, Hong and Kinshuk, 2003). MRS are proposed in contrast to the content creation tools included in commercial GPELEs such as WebCT and LearningSpace that offer specialized WYSIWYG interfaces for educational content creation. Layered presentation of the learning content is also proposed as helpful for learners of different learning styles (eg. INSPIRE: Papanikolaou, Grigoriadou, Magoulas and Kornilakis, 2002). Real life activities are also proposed as essential for the design of e-learning environments (Dillenbourg, et al., 2002; Tretiacov and Kinshuk, 2003; Zikouli and Kordaki, 2004). Tools for forming concept maps as well as for forming flow-charts in student collaboration within e-learning settings are also proposed (e.g. SCALE: Grigoriadou, Gogoulou, Gouli and Samarakou, 2004; SYNERGO: Voyatzaki, Christakoudis, Margaritis and Avouris, 2004). In addition, simulation programs are integrated in computer learning environments to support learners in actively exploring the learning concepts in focus (Grigoriadou and Kanidis, 2003). Microworlds including a number of appropriately designed tools to support learners in actively constructing solutions to the tasks given are also reported (eg. Cabri-Geometry II: for the learning of the Euclidean Geometry, Laborde & Strasser, 1990). Moreover, tools that help students' active experimentation in MRS have been also used in the design of computer based learning environments (eg. L.E.C.G.O.: a computer environment for the learning of Programming and C, Zikouli, Kordaki and Houstis, 2003). Finally, an interesting trend on the development of learning environments is the linking between digital texts and exploratory and simulation educational software (eg.Absorb Mathematics, http://www.crocodile~clips.com/absorb/math).

A GENERAL ARCHITECTURE FOR THE DESIGN OF SPELEs

In this section, an architecture of a typical representative of SPELEs is presented. The construction of this architecture was based on modern constructivist and social theories mentioned in the previous section. An attempt also was made to exploit the advantages of the reported experience regarding the design of specific Computer Based/Internet Based learning environments and to integrate this experience in the design of the architecture proposed. On the grounds of modern theories of knowledge construction a number of specifications were formulated and were used for the construction of the architecture. The proposed architecture consists of five parts: (A) organization of the learning content, (B) learning activities, (C) learner activity space, (D) learner assessment, and (E) learner communication. The description of the design of these parts is presented below:

Part A: *organization of the content.* This part of the design of SPELEs includes specifications related to the design of the content of a specific learning subject. The content is organized into four hyper-linked layers. In each layer different forms of the content are presented. The forms of the content in each layer are presented bellow:

First layer: The basic structural element of the content is the learning activity. Therefore, the content is organized as a group of fundamental, appropriate, efficient learning activities which are adequate for the learning of each specific learning subject. The selection of activities is crucial in order to focus on the basic concepts of each learning subject and to avoid those of minor importance. For the design of these activities the context of modern theories of learning is appropriate. The design specifications for such activities will be presented in the next section (Part B). The representation of each activity in multiple representation systems is also important for the design of an attractive content that will satisfy different learning needs. A variety of representation systems can be used, such as: animations, full text, transparencies, hypertext, multimedia, diagrams, tables, graphs, etc.

Second layer: The content is organized as a glossary consisting of a brief presentation of each learning concept.

Third layer: The content is organized as an encyclopaedia of the learning concepts. Here, these concepts are presented in details.

Fourth layer: The content is presented in reference to a wider context consisting of a variety of resources such as: url's, books and references.

The selected activities presented in the first layer are hyper-linked with the associated concepts, formulas and other learning elements which are implied in their performance. In fact, the four layers of the content mentioned above are hyper-linked. In this way the learners have the opportunity to access learning information in a form that is more appropriate to their cognitive needs.

Part B. *Learning activities*. Learners can take significant advantages in their learning process when they are engaged in appropriate learning activities. Modern constructivist and social views of learning constitute a fruitful theoretical framework for the design of appropriate learning activities. This part of the design of SPELEs includes basic specifications related to the design of constructivist learning activities suitable in a computer context. In terms of design specifications, these activities:

a) focus on both:

   (i) the fundamental aspects of the learning subject, and

   (ii) the specific learning points where the learners illuminate difficulties

b) create interest. Thus, they enable strong motivation for the learners. Such activities are situated in the context of the learners' every-day life.

c) stimulate the learners' higher mental functions. Problem solving activities are appropriate as they enable analytical and synthetical thinking skills as well as critical thinking.

d) are open. This means that these activities allow the learners to:

   (i) perform them in many ways. Thus, learners have the opportunity to construct their own solution strategies and to express their inter- and intra-individual differences.

   (ii) construct solution strategies in different representation systems.

   (iii) have control over their learning. This means that the activities can be solved using such representation systems that provide appropriate feedback (intrinsic visual and/or explicit numerical). Learners can reflect on the feedback of their actions and then they have the opportunity to correct their solution strategies.

   (iv) express different kinds of knowledge such as: their previous knowledge, school-knowledge, intuitive knowledge, real life knowledge, visual knowledge, etc.

(v) reflect on a flexible feedback. That means that the provided feedback is designed in correspondence to the different kinds of knowledge that the learners can express. So, they can reflect on the provided feedback and can correct their solution strategies.

e) encourage the learners to experiment by handling primary sources of data while at the same time acquiring hands-on experience.
f) do not demand of the learners extra complicated knowledge from other disciplines.

Part C. *Learner activity space*. This part of the design of SPELEs includes specifications for the design of *'learner activity space'*. 'Learner activity space' is a virtual place where the learners can actively construct their own knowledge by performing the selected group of learning activities, using a variety of specifically designed tools. The design of the provided tools within a 'learner activity space' is strongly related to the specific learning subject. The definition of both the basic concepts that structure a specific domain of knowledge and the most representative and essential activities for the learning of its concepts is crucial for the design of the tools included in the 'learner activity space'. A successful design has to avoid the allowance of a superabundance of tools while at the same time to focus on the construction of a limited number of tools that can successfully help the learners perform the basic learning activities, mentioned above. The main objectives of the design of the provided tools are to provide the learners with opportunities to:

a) perform different solution strategies to the selected essential learning activities, thereby expressing their individual learning differences,
b) perform the same solution strategy using different representation systems,
c) solve different classes of essential activities for the learning of each specific learning subject,

d) overcome basic difficulties regarding each specific learning subject.

The differentiation of representation systems and their associated tools is closely related with the differentiation of their cognitive transparency. Some representation systems and tools can help learners handle primary sources of data while simultaneously acquiring hands-on experience. Some other systems and tools can help learners to manipulate more sophisticated types of data using different types of data-manipulation tools, such as: tables, graphs, equations etc. Other systems and tools as for example, real-life simulations can help learners to construct knowledge by exploring dynamic representations of the learning concepts. Learners can take advantage of the variety of the provided tools in their attempts to construct different solution strategies for the given tasks. To design tools that support the construction of different problem solving strategies, the research on how the learners cope with each specific learning subject is crucial. By exploiting the results of such studies in the design of the provided tools the designers can safely claim that such tools are reliable as learning tools and that they can successfully support a variety of learners.

Part D. *Learner assessment*. This part of the SPELEs design includes specifications related to the design of assessment activities. From the constructivist perspective, assessment can become a valuable tool for learning. From this perspective, the emphasis of assessment is placed on each individual's learning processes and not exclusively on her/his learning outcomes. Holistic real-life activities can be used as a basic structural element of the learners' assessment. So, a combination of methods can be used, such as:

- self-assessment by reflecting on appropriately designed intrinsic and/or extrinsic feedback,

- self-assessment by answering multiple choice questions, automatically corrected by the system
- longitudinal assessment by the teacher by providing the learners' with opportunities to add in electronic portfolios posting their work over an extended period,
- assessment by both the teacher and the learner based on project-work,
- assessment by participating in appropriately designed educational games. Games are powerful tools for assessment, as they motivate the learners to be actively involved in their learning.

Part E. Learner *communication*. This part of the design of SPELEs includes specifications related to the design of communication activities. The role of holistic real-life activities is central in the communication process. Learners communicate in a variety of group settings in order to perform the given activities. They can learn by negotiating their knowledge with the knowledge of their colleagues, including their teachers, using synchronous and asynchronous communication and combinations of both. To support learners in performing all these communications, the system can support a large number of asynchronous conferences.

<u>The proposed design methodology for SPELEs</u>

The design methodology for SPELEs to meet the specifications described above consisted of seven basic steps. These steps are presented below:

Step1. Defining the basic concepts of the specific learning subject. At this point it is crucial to emphasize the basic concepts that structure the specific domain of knowledge.

Step 2. Defining the appropriate, essential learning activities for the learning of the concepts defined in the previous step (Step 1).

Step 3. Investigating how the learners perform the essential activities selected for the learning of each specific subject. At this point, the role of field studies is crucial for the establishment of both: (a) the learners' possible paths towards the performance of the given tasks, including their mistakes and (b) the learners' main difficulties.

Step 4. Defining the appropriate representation systems to appropriately meet the learners individual learning differences as they emerged from the field studies performed using real students.

Step 5. Designing the appropriate tools included in the 'learner activity space'. This step, consists of the design of the appropriate tools that learners can use to perform the activities selected in Step 2 using the representation systems defined in the previous step (Step 4).

Step 6. Designing the tools for assessment, so that the learning based in the performance of the activities selected in Step 2 using the representation systems and tools (defined in steps 4 and 5) can be evaluated.

Step 7. Designing the facilities to provide for communication in order to give the learners the opportunity to communicate in multiple ways to perform the activities selected in Step 2 using the representation systems and tools defined in steps 4 and 5.

THE DESIGN OF THE F.P.S.D. E-LEARNING ENVIRONMENT: A CASE STUDY

In this section, the design of a SPELE using the proposed architecture is presented. This environment is designed for the learning of the concepts of Files and of Peripheral Storage Devices. Part of the design of this software is reported in Venakis, Giannakopoulos, Pirli & Kordaki, (2002). The technical issues regarding the implementation of F.P.S.D. are also presented.

Files are basic information storage units and the need to organize them is primal and fundamental so the user can access them quickly and easily. In addition, peripheral storage media are a substantial and necessary part of computer systems. Despite this fact the concept of files and their management as well as the concept of peripheral storage media are not cognitively transparent for primary and secondary level education learners (Kordaki, 2004). In order to give High School students the chance to understand in an active way the previously mentioned concepts, an Internet-based multiple representations learning environment was created. The environment's design was based on the framework of the proposed architecture described in the previous section. The design and the implementation of such an environment for the learning of these specific concepts has not been yet mentioned in the literature. The basic steps of the design methodology of this software as well as the presentation of its functions are shown further down:

Step 1 and Step 2. Defining the basic aspects of files and of peripheral storage media for secondary level education students. The main aspects of the previously mentioned subjects and the selected appropriate learning activities are presented below:

- *Recognising different types of files* such as: system files, specific programs, files created by the user. Providing the learners with a variety of files of different types and asking for recognition is an useful activity.
- *Managing Files*. Here, the finding of a criterion to sort files in classes and then to store them in folders is important. So, providing the learners with a number of different files and asking for sorting is an appropriate activity.
- *Orientation in a file microworld*. Here as well, the searching for a specific file is an important activity.
- *Recognising the limited capacity of a storage medium*. At this point the task of storing a variety of files in a simulation of a storage medium such as, a hard disk, a CD-ROM and a

floppy disk, each with given capacity, (small in the case of a hard disk), can give the learners a sense of their respective limited storage capacities.

- *Disk formatting*. Here as well, the use of a visual simulation of the disk formatting operation is important in providing the learners with a visible meaning to such an invisible operation.
- *Basic operations* that can be performed on the content of a file. Such operations are: paste, cut, copy, delete, etc. Activities that provide the learners with opportunities to edit different types of files can be helpful for them.

Step 3. Investigating how the learners learn the specific learning subject. To clarify the ways and the difficulties of secondary level students concerning the concepts of files and of peripheral storage media mentioned above, a field study was realised, as there were no references in the literature. The main results of this study show (Kordaki, 2004) that students found it difficult to:

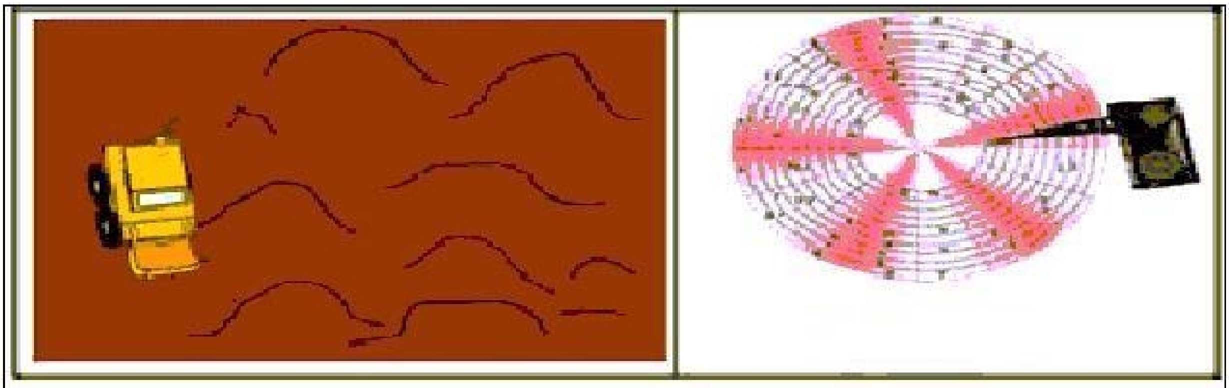
- Recognise various types of files with the exception of: text documents, sound files and bitmap files
- Find a criterion and use it to sort files in folders
- Find a specific file classified in a folder
- Resolve the different operations that can be performed on the content of a file, such as: paste, cut, copy, delete, copy & paste, cut & paste, etc.
- Recognise Read Only files
- Recognise that a storage medium and especially a hard disk have limited capacity
- Understand the disk formatting operation

Based on both the work described above and the general specifications for the design of SPELEs, the anatomy of F.P.S.D. involved the design and the implementation of the following five parts:

Part A: *organization of the content.* The content is organized into four layers:

First layer. In this layer, the basic structural element of the content takes the form of learning activities. Here, two types of activities are used: (i) simulations of real life activities where operations and objects were used as metaphors of computer-based operations and objects related to the specific learning concepts and (ii) computer activities using computer-based operations and objects related to these concepts.

The presentation of real life activities is done with the use of multimedia and moving image techniques. More specifically, as far as peripheral storage media are concerned, a hard disk is compared to a wardrobe, a CD-ROM is compared to a rucksack and a floppy disk is compared to a handbag. Real life objects of different size and nature act as data and are stored in the aforementioned storage media. Files are compared to jars where the inserted data is coffee or jam. Folders are compared to shelves where the jars are classified. The jars are classified according to their content. The concept of disk formatting is presented through a real life metaphor-activity: the clearance of a field by a bulldozer in order to become suitable for sowing seed (Picture 1a).



Picture 1a Picture 1b

Picture 1. Disk Formatting

The selected metaphors of real-life activities are situated in the context of young students every-day lives and are easily understandable. The moving, colorful presentation of the associated images can create an internal motivation for the students as well. These metaphor activities can act as scaffolding activities for the students' learning of the analogous activities performed using computer-files, folders and peripheral storage media (Picture 2b). These last types of activities are also demonstrated to the students, again using moving image techniques.

More specifically, the activities of sorting files and of classifying them in folders in the context of a typical computer environment were presented to the students, using the previously mentioned techniques. Moreover, activities of storing files and folders on a real hard disk and on real CD-ROM as well as on a real floppy disk were demonstrated. Furthermore, the process of formatting a real disk is displayed (Picture 1b).

Second layer. In this layer, the main points of the learning concepts are presented in brief in the form of written text.

Third layer. In this layer, an analytical description of the learning concepts in the form of text is presented. In addition, the learner can proceed from a brief presentation of the main points to a detailed presentation via hyperlinks.

Fourth layer. In this layer hyperlinks to web sites with content relevant to the learning concepts above are available to the learners so that they can further expand their knowledge.

Part B. *Learning activities*

The design of learning activities took into account the students' difficulties regarding their understanding of Files and Peripheral Storage Devices as they emerged from the information collected from the field study mentioned in Step 3, previous section. The categories of learning activities which have been formed are presented bellow:

1st Category of Activities. *Exploring a file microworld.* Here, a variety of files are presented to the learners and they are asked to recognize the various types by their name or icon. If this is impossible, students can search for extra information by double clicking on each file.

2nd Category of Activities. *Management and orientation in a simulation of a real life microworld*. Learners are provided with a number of real-life objects so that it will be impossible for them to remember each one and are then asked to store these objects in a variety of storage media. Next, they are asked to find a specific object. This type of activity enables the students to develop their cognitive skills regarding classification and orientation in a context consisting of simulations of real life objects and operations.

3rd Category of Activities. *Management and orientation within file and peripheral storage media microworld*. Learners are provided with a number of computer files so that it will be impossible for them to remember each one and then they are asked for classification in computer folders. Next, they are asked to store the folders in a variety of peripheral storage media such as: a hard disk, a CD-ROM and a floppy disk. Finally, they are asked to find a specific file. This category of activity enables the students to develop their cognitive skills regarding classification and orientation in a microworld consisting of computer files and operations.

4th Category of Activities. *Transformations in a file microworld*. Learners are provided with various files eg. document files, image files and then they are asked to select parts of them in order to produce new files using basic file operations such as cut past, delete, copy, etc. This category of activity enables the students to develop their cognitive skills regarding analysis, and synthesis in a microworld consisting of computer files containing different kinds of data. This category of activity also enables the students to develop their technical skills regarding basic file operations mentioned above.

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Part C. *Learner activity space*

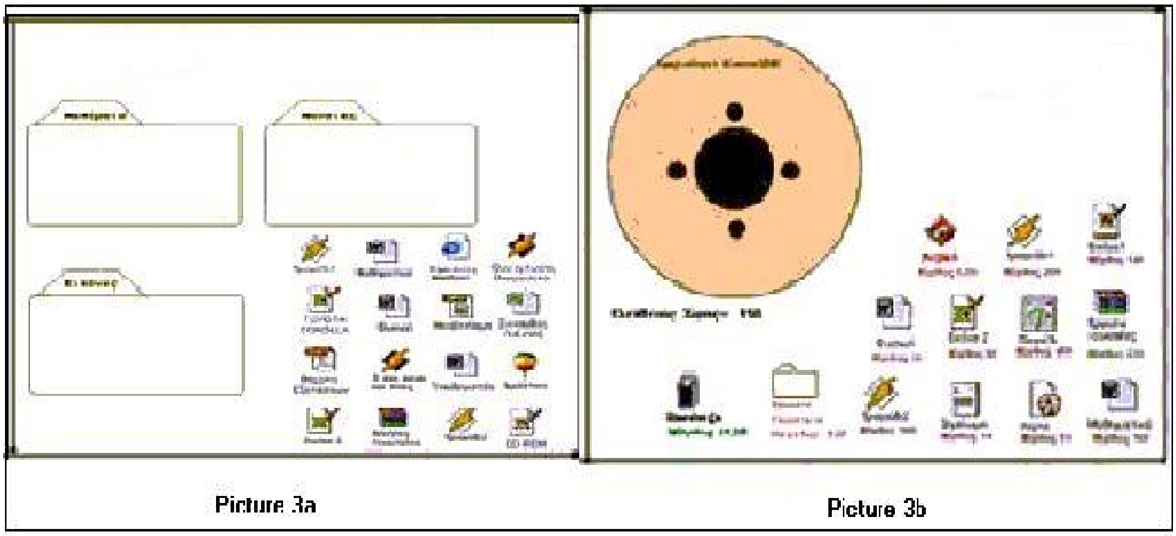
Representations and tools for the active performance of the selected categories of activities relating to the concepts of files and of peripheral storage media were designed and are presented below:

Real life representation systems. A variety of real-life objects are provided to the students. Students can drag and drop these objects using the mouse in order to store them in storage places. More specifically, here the student is asked to sort some real life objects in a kitchen cupboard, moving them with the mouse. These objects metaphorically represent files, whereas the cupboard shelves metaphorically represent folders (Picture 2a). These objects are different from those used in the respective content presentation activities (Part A, previous section), in order to compel the students to think and act thus preventing them from reproduction (Picture 2b). In the context of these representation systems students can perform activities of the 2nd Category (Part B, previous section).

Picture 2. Everyday life representation systems

Representations of files used in actual computer interfaces. A variety of different types of computer-files are presented to the students. Actual computer-folders are also provided (Picture 3a). In this context *actual file sorting activities* can be performed. Two types of these activities can be performed. The one type involves the student in sorting various files in folders in the way she/he prefers. More specifically, the student is given three computer folders called “Courses”, “Music” and “Pictures”. A number of various file icons are provided for sorting in folders. These files represent: photograph files, music files and files relevant to school courses. The student is asked to store the files in the folders in any way she/he likes. After the sorting is finished, the student is asked to find certain files (different ones in each execution of the program), so that she/he will realize why it is useful to sort files in folders correctly. The other type of sorting activity is almost identical to the previously mentioned, differing only in the fact that the program does not allow the student to sort a file in a folder where it does not match. This was decided in order to give the learner the opportunity of realizing how files can be correctly sorted in folders. (Picture 3a). In these representation systems students can perform activities of 1st and of 3rd categories (Part B, previous section).

Representations of actual computer-based storage media. Moreover, simulations of peripheral storage media with a certain capacity are provided, such as: a hard disk, a CD-ROM and a floppy disk (Picture 3b). Students can also drag and drop the folders and the files using the mouse in order to store them in these peripheral storage media. Each file has a set size which is inscribed on it, while the total size of all the files together exceeds the capacity of the hard disk. In this activity the student is asked to store some computer files in a storage medium of a certain capacity. This was considered necessary in order for the student to realise that a storage medium and especially a hard disk has finite capacity. In these systems activities of the 3rd category (Part B, previous section) can be performed.



Picture 3. Representation systems used in actual computer interfaces

Games as representation systems. A labyrinth game was designed to support students learning of basic file operations such as copy, past, delete, cut, etc. (The game is under implementation). In the context of this game each student can visit the different rooms of the labyrinth but she/he cannot go out until correctly performing some specific basic file operations. In some rooms new computer files are presented to the visitor to manipulate. In other rooms the visitor is asked to perform specific basic file operations. Learners are asked to perform two types of activities regarding file transformation: a) to use different files and perform the necessary transformations in order to produce a pre-defined file (by the teacher) and b) to to use different files and perform transformations in order to produce their own files. The game was designed to assess automatically the first type of activity. The game is also designed to provide the learners with various files eg. document files, image files etc. as well as the basic file operations such as cut past, delete, copy, etc. In the context of these representation systems students can perform activities of the 4th Category (Part B, previous section).

(Part C is referred to Step 4 and Step 5 of the proposed design methodology, previous section)

Part D. *L*earner assessment

Assessment by the teacher. On entering the software environment, the learner is asked to give a login name and a password. For new users there is a link for registration. The system asks for the user's personal data in order to create a log file of her/his actions which can be used as a source of information for further study, research and assessment by the teacher and the researcher.

Self-assessment. The software enables the learner to evaluate herself/himself through a game in the form of a quiz. Young learners are interested in quizzes and use them to amuse themselves in their everyday lives. The questions aim to investigate and illuminate the learners' difficulties regarding the learning concepts. In each step the learner has to choose between similar answers to the question posed. If she/he chooses the most correct answer, the quiz proceeds to a question on another point, otherwise it poses a new question on the same point. The answers are constructed in such a way as to enable the student to realize where she/he made a mistake. The same process goes on for four questions concerning the same sub-concept. The learners' answers are not labeled by the system as right or wrong. At the end of the game, each learner gets a score, which is the total sum of the scores that she/he got by answering the questions throughout the test. The winner of the game is the learner who got the lowest score.

Longitudinal assessment. In this context, electronic portfolios can be created for each student where she/he can post her/his work. In addition, project-based assessment can be performed by dividing the students into groups and assigning a specific project to each group.
(Part D is referred to Step 6 of the proposed design methodology, previous section)

Part E. Learner communication

The software environment enables the students to communicate with one another and with their teacher, asynchronously, using e-mail, text-chat, forum, tele-conference and web boards where every group of users can post a message.

(Part E is referred to Step 7 of the proposed design methodology, previous section)

The software's technical characteristics. For the software's implementation the Macromedia Flash 4 & 5, Javascript and PHP v. 4.0.6 technologies were used as well as the database MySQL v. 3.23.31. Minimum system requirements are, Pendium II, 300MHz, memory 64MB, Hard Disk space 2MB and Internet Explorer version 6.0 or higher.

THE PILOT EVALUATION STUDY OF F.P.S.D.

The context of the pilot study

The environment's pilot evaluation study was conducted under the constructivist perspective emphasizing the student's evolution during her/his interaction within a learning environment (von Glasersfeld, 1990). In terms of methodology, this research is a qualitative study (Cohen & Manion, 1989). The main objectives of this study were to investigate : a) the students' prior knowledge of the concepts in question, b) how the students' knowledge progressed during their interaction within the context of the F.P.S.D. learning environment, and c) the functionality and the usability of the software.

The study was conducted in the 3rd High School of Egion with the participation of 10 students of the 2nd grade (14-15, years-old) and lasted 2 hours. The students worked on computers in pairs exchanging places so that everyone could interact with the software. Initially the students were asked to fill in an answer sheet, which served to investigate their prior knowledge regarding the specific learning concepts. The same answer sheet was given to them at the end of the pilot phase in order to investigate the evolution of their conceptions. The researchers' part in the study was mainly as observers, intervening only when it was necessary so as not to influence the students' actions, but to record anything they said or did during their interaction with the system. The data sources of the study were the aforementioned notes and the log files which were created. The communication forum was not used during the software's evaluation. This was done mainly due to lack of time, since the asynchronous nature of this type of communication requires long-term involvement of the students with the software.

Analysis and interpretation of the pilot phase results

The student's prior knowledge. Even though the students participating in the pilot study had been taught this specific subject recently, their answers to the answer sheet questions showed that almost all of them had failed to understand the concept of file, and they were confused about folders and file sorting. Few students (two students) seemed to understand the importance of the existence of different storage media, and nobody seemed to know anything about magnetic medium formatting. No student had ever used the Internet and only one had a personal computer.

The students' interaction with the software environment.

a) Introducing the F.P.S.D. environment. All students needed help in order to complete the "new user insertion form", since this was the first time they had come in contact with an Internet application and especially with an environment which required new user registration.

b) The role of the home page. All students expressed their admiration for the introductory bright animations presented in the home page of F.P.S.D. All of them devoted an amount of their time to enjoying these images.

c) The role of the game. It is noteworthy that the students' first choice was the 'Quiz', presumably because they were more familiar with this word than with other activities. However, most of the students spent only a few minutes on it because at this point, they could not meet its requirements.

d) *The role of real life activities in the content presentation.* The next choice for most students (eight students) was the presentation of the learning content through real life activities, presented with the use of moving images. The students' answers to the researchers' questions showed that most of them understood the analogy of real life objects and activities with the activities of sorting and storing using actual computer operations and objects for peripheral storage media, files and file sorting. There were three students who could not understand the above analogy and the meaning of the presented activities, so, they had to repeat it a few times. The point which was completely opaque for the students had to do with the magnetic medium formatting presentations. The concept of 'disk formatting' was new to all students.

e) *Student interactions within the 'learner activity space'.* All students visited the 'learner activity space'. The students performed the activities in the order that they were presented on the interface. Most of them dedicated a lot of time to the real life activities and all completed them successfully. However, many students (eight students) performed the 'sorting files in folders' activities in a random and incorrect way and when they were asked to retrieve certain files from the folders they had difficulty in doing so. After several attempts they performed the activity of file sorting correctly. It is worth mentioning that, there were some students (two students) who sorted the files correctly from the beginning. In the specific activity where the student is asked to store files of a set size in a hard disk of finite capacity, few students (two students) understood why they couldn't store all the files on the disk. One asked *'why can't this file go into the disk'*, the researchers replied that a hard disk has finite capacity.

f) *Self assessment in a game's context.* Next, the students tried the quiz. Initially they all said they would prefer a system that informed them whether their answers were right or not. However, because they didn't know if their had answered correctly and where they had made mistakes, when they saw that other students achieved better scores they continued to play again and again. In the end, they admitted that it was better this way because they found most correct answers on their own.

g) *Students' navigation through the text-based presentations of the learning content.* It is worth noting that, the students spent very little time reading the main points concerning the learning concepts which was presented in the form of written text and hardly any time reading the detailed descriptions of the subject. The majority resorted to the brief description after the researchers' urging so they could get information about disk formatting. Others resorted to it in order to fill in the final answer sheet.

Finally, the analysis of the students' answers to the answer-sheet given after their interaction with the software showed that this software helped them to a certain degree in understanding the concepts of files and folders and less in understanding peripheral storage media and disk formatting.

DISCUSSION AND FUTURE TRENDS

The concept of Special Purpose E-Learning Environments (SPELEs) was presented in this study. In contrast to the concept of General Purpose E-Learning Environments (GPELEs) which incompletely support the learning of any learning subject, SPELEs are designed to support more efficiently the learning of a specific subject matter. A typical architecture for the design of SPELEs was proposed. This architecture was based on interpretations of constructivist and social views of learning in the Internet context.

More specifically, the proposed architecture support the design of such e-learning environments where learning is realized in a context consisting of: (a) content presentation using as a basic structural element the learning activity performed in multiple hyper-linked representation systems, (b) constructivist, open real-life learning activities, (c) active learning using multiple representation systems and tools designed by taking into account specific research studies investigating how the learners cope with the concepts of the specific learning subject, (d) tools which assist experimentation using primary sources of data while at the same time providing opportunities for hands-on experience, (e) representation systems which can act as metaphors of real life activities, (f) multiple ways of assessment emphasizing the learning process and not only the learning outcomes, (g) multiple ways of communication emphasizing combinations of both group and whole class conferences, using synchronous and asynchronous modes.

The proposed architecture consisted of five parts: (A) organization of the content of a specific learning subject, (B) learning activities, (C) learner activity space, (D) learner assessment, and (E) learner communication.

A 7-step methodology was formed for the construction of the architecture above:

Step1. Defining the basic concepts of the specific learning subject. *Step 2.* Defining constructivist, essential learning activities for the learning of the defined concepts. *Step 3.* Investigating how the learners perform the essential activities selected for the learning of each specific subject through field studies using real students. *Step 4.* Defining the appropriate representation systems to meet the learners' individual learning differences. *Step 5.* Designing the appropriate tools included in the 'learner activity space', *Step 6.* Designing the tools for assessment, and *Step 7.* Designing the facilities provided for communication.

In the framework of this architecture a SPELE was constructed for the learning of the concepts of Files and Peripheral Storage Devices (F.P.S.D.). The F.P.S.D. was evaluated in a pilot study using real students. Here, the parts of the proposed architecture are discussed in relation to the data which emerged from this pilot study.

Part A. *Organization of the content.* The content was organized in four hyper-linked layers. In the first layer, the content was organized as a group of two types of activities: (i) simulations of real life activities where operations and objects were used as metaphors of computer-based operations and objects related to the learning concepts in question and (ii) computer activities using computer-based operations and objects related to these concepts. The necessary concepts related to the performance of these activities were hidden and illuminated according to the needs of each individual learner via hyperlinks. These concepts were presented in brief (in the second layer), in details (in the third layer) and in a wider context including a variety of resources such as url's, electronic books etc. (in the fourth layer).

As it is shown in the results of the pilot evaluation study of F.P.S.D. the students mainly paid attention to the two different types of learning activities used for the presentation of the learning content. It is worth noting, that the students were attracted by the real life activities which were used as metaphors of the activities using computer operations and objects. Even though the activities were hyper linked with brief and analytical descriptions of the necessary knowledge for their performance, a small number of students accessed the brief descriptions while no one tried the analytical ones.

Part B. *Learning activities.* The categories of the learning activities were designed by examining: a) the basic concepts that constitute the learning of files and peripheral storage media for secondary level education students and b) the students' approaches and cognitive difficulties in their learning of the concepts in question. These approaches and difficulties had been investigated by performing field studies using real students. The basic aspects and skills regarding the concepts above were: a) the recognition of various types of files b) file management, c) orientation in a file microworld, d) basic operations that can be performed on the content of a file, e) the recognition of the limited capacity of a storage medium, and f) disk formatting operations. The investigated students' difficulties related to all these aspects.

As a result, four categories of learning activities were designed: 1) Exploring a file microworld, for the understanding of (a) above, 2) Management and orientation in a simulation of a real life microworld, for the understanding of (b, c, e and f) above, 3) Management and orientation within file and peripheral storage media microworld, for the understanding of (b, c, e and f) above, and 4) transformations in a file microworld, for the understanding of (d) above,.

The designed activities are well situated in the context of modern learning theories as they were: a) open, enabling the learners to perform them in alternative ways as well as to express different kinds of knowledge such as: school-knowledge, intuitive knowledge, real life knowledge, visual knowledge, b) interesting, as they were situated within the students' world, c) appropriate for the learning of the basic aspects of the subject matter, d) cognitively challenging since they focused on management and orientation of files, e) self explanatory in that they provided the students with appropriate feedback for making corrections in their sorting and storing attempts, f) practical, enabling the learners to experiment by handling primary sources of data while at the same time acquiring hands-on experience, g) not demanding, as the learners were not expected to have extra complicated knowledge from other disciplines.

As the results of the pilot study show, the designed activities occupied the attention of all students as well as their active participation in the pilot-evaluation experiment. More specifically, the use of real world activities, objects and operations as metaphors for the activities performed in the computer word using its functions and objects greatly helped in the understanding of the aforementioned concepts. Moreover, students were helped by the activities which led them to a cognitive conflict, such as the demand to find certain files stored in folders and the storing of files of total size greater than the capacity of the available hard disk.

Part C. *Learner activity space.* The design of the representation systems and their associated tools provided to the students for active learning, within the context of 'learner activity space', was based on the proposed methodology for the general design of SPELEs. So multiple representation systems and their associated tools were designed and implemented. There were: a) Real life representation systems. These systems were used to support the performance of activities included in the 2nd category (Part B, previous section), b) Representations of files used in actual computer interfaces. In these representation systems students can perform 1st and 3rd category activities (Part B, previous section), c) Representations of actual computer-based storage media. These systems were used to support the performance of activities included in the 3rd category (Part B, previous section), and d) Games used as representation systems to support the performance of activities included in the 4th category (Part B, previous section).

The analysis of the data which emerged from the pilot evaluation study of F.P.S.D. shows that all the provided tools were used by all the students who participated in this experiment. Moreover, this study shows that the previously mentioned systems and tools: a) helped the students performance of the designed categories of learning activities and b) supported them in expressing different kind of knowledge regarding the learning concepts, such as: school-knowledge, intuitive knowledge, real life knowledge and visual knowledge.

Part D. *Learner assessment.* F.P.S.D. supports a variety of ways for assessment: a) assessment by the teacher, by studying the logfiles automatically created by the software. These files were also used to evaluate this experiment, b) Longitudinal assessment, by using electronic portfolios and c) Self-assessment by participating in a specifically designed game.

Despite the fact that the F.P.S.D. supports a variety of ways for assessment, the short duration of the experiment limited the students to trying self assessment by participating in the provided game in the form of a quiz. This quiz does not provide explicit feedback in the form of messages that inform the user of the correctness of her/his answers to the questions provided. The questions are organized in such a way so that in the case of a wrong answer another similar but easier question is posed for the learner to answer. A group of four similar questions are available for the learner to experiment with. As demonstrated by the data which emerged from the pilot evaluation study of F.P.S.D., students enthusiastically and tirelessly played the game more than once until they gained good results!.

Part E. *Learner communication*. The limited time dedicated to this pilot evaluation study does not provide us with data for the communication that could be performed within the context of F.P.S.D. More time is needed to gather data regarding effective communication using the related facilities of F.P.S.D.

Future trends

As far as magnetic medium formatting goes, it is obvious that the software should be modified in order to allow the student a deeper observation of this procedure. The design of the interface could also be changed so that the objects it contains will be more interesting for the students. Further study with a greater sample of students, as well as testing the communication facilities, and the game designed for experimentation with basic file operations (which is under final testing) could bring to light more interesting issues regarding the software and its influence on the students' learning processes.

Finally, the core of all specifications described for the design of a SPELE was taken into account for the design of the F.P.S.D. Even though improvements and developments for the F.P.S.D. e-learning environment can be proposed it is worth mentioning that a sense of security came as a result of its pilot evaluation experiment. This sense was grounded both in the results based on the answer sheet completed by the students after their interaction within the context of F.P.S.D. and on their enthusiastic participation in this experiment.

CONCLUSIONS

This study demonstrated the background, the implementation and the pilot evaluation of a Special Purpose E-Learning Environment (SPELE) for the learning of concepts of Files and Peripheral Storage Media. This environment was pilot evaluated in the field with real students. The analysis of the data which emerged from this experiment verifies the methodology used and the core specifications of the proposed architecture for an effective design of a SPELE. More specifically, the design of this environment was based on constructivist and social theories of learning which were interpreted in the Internet context thus forming a general architecture for SPELEs. This architecture consisted of five parts: (A) organization of the content of a specific learning subject, (B) learning activities (C) learner activity space (D) learner assessment and (E) learner communication.

The main points of the proposed architecture which were addressed by the experimental evaluation study emphasize: a) activity based presentation of the content, b) multiple representation systems and tools assisting both the presentation of the activities that compose the content and the performance of learning activities so as to support various learners in expressing their individual learning differences, c) essential, problem solving, open, holistic, real life activities, d) real life operations and objects used as metaphors of computer operations and objects, e) games as a motivating way for self-assessment, f) appropriate feedback to lead the students firstly to a cognitive conflict and next to self correction. More research is needed to extend the constructed prototype for the learning of other related concepts as well as for the evaluation of the provided communication facilities.

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