UNIVERSAL METHODOLOGY FOR THE DEVELOPMENT OF THE MULTIMEDIA LEARNING SYSTEMS AND ITS IMPLEMENTATION IN THE SUBJECT COMPUTER SCIENCE IN THE HIGH SCHOOLS IN MACEDONIA

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Abstract: This paper deals with the theoretical acknowledgements concerning the learning systems on a conceptual level and the methodology for complete development of multimedia learning systems (MLS). For the realization of MLS, standards for optimal characteristics of different multimedia components have been defined. The architecture of the MLS consists of a managing subsystem in Visual Basic and a subsystem of resources that consists of HTML documents and Access database. The universality of the system is in the managing subsystem and in the created database. By using this methodology, MLS is realized in Computer Science in the high schools in Macedonia.

Keywords: learning system, MLS, multimedia, computer science, Informatics, Computer Science

1.   Introduction

We have all experienced periods of optimal learning when we are so focused on what we are learning that nothing else matters to us. The repetition of such a period of optimal learning is a task for the teachers in all environments, such as in the schools, the work place, in the army etc.

To achieve such periods of optimal learning, the theoreticians constantly insist on greater use of technology, and especially the use of computers in the learning process. They see an enormous potential in the computer technology that will help in replicating these optimal learning periods. With the help of the computer technology different learning systems are developed, and the multimedia learning systems are among the most popular ones.

2. Learning Theories

Interventions in the learning process can have an effect on many different things. The intervention levels that depend on someone or something and on how things are done, are defining factors of the learning theories. These factors help to extract many different theories that evolve and change as we discover new ways in approaching the human cognitivity. The spectrum of learning theories consists of many approaches or ways to explain how people learn. They provide enough knowledge to enable critic examination of the use of the computer as a learning tool.

The spectrum extremes of the learning theories consist of the behaviorists' and constructivists' studies. The behaviorism and constructivism are more concepts than theories (i.e. meta-theories) and they unite more theories, i.e. they are bipolar in their aspects.

The behaviorism, as a learning approach, is usually referred to as a directed instruction. The main stress of the behaviorism is put on the perceptive learning indicators. In contrast to this learning approach, the cognitive psychologists state that learning is similar to the mental processes in the brain. The behaviorists do not deny the existence of these mental processes, but they acknowledge their existence as a non-observable indication of learning.

The constructivism is recognized as a unique learning theory. It can also be connected with the cognitive psychology, because as a learning theory, it focuses on the student's ability to mentally construct the significance of his environment and to create his own learning. The term constructivism is linked with the cognitive and social constructivism.

In the behaviorist learning theory, the constructivists criticize the behaviorist implication that knowledge is separated from the human mind and that the knowledge has to be transferred to the student in a teacher based approached. This is fundamentally opposite to the constructivist learning theory.

According to the constructivist theory, all people have the opportunity to "construct" knowledge in their own mind through the process of discovering and problem solving. The spreading of this process that can be achieved in a natural way is a defining factor among those who support this theory.

According to [5] today's learning processes, one can summarize them in eight points:

1. From linear toward hypermedia;
2. From instruction toward construction and discovery;
3. From teacher focused education toward student focused education;

4. From learning through material absorption toward learning how to find things out and how to learn;

5. From learning at school toward global learning that lasts the whole life;

6. From one way of learning which is the same for everyone toward an adaptable way of learning;

7. From learning as a torture toward learning as fun;

8. From the teacher as a transmitter of knowledge toward the teacher as a person who facilitates and makes the learning process easier.
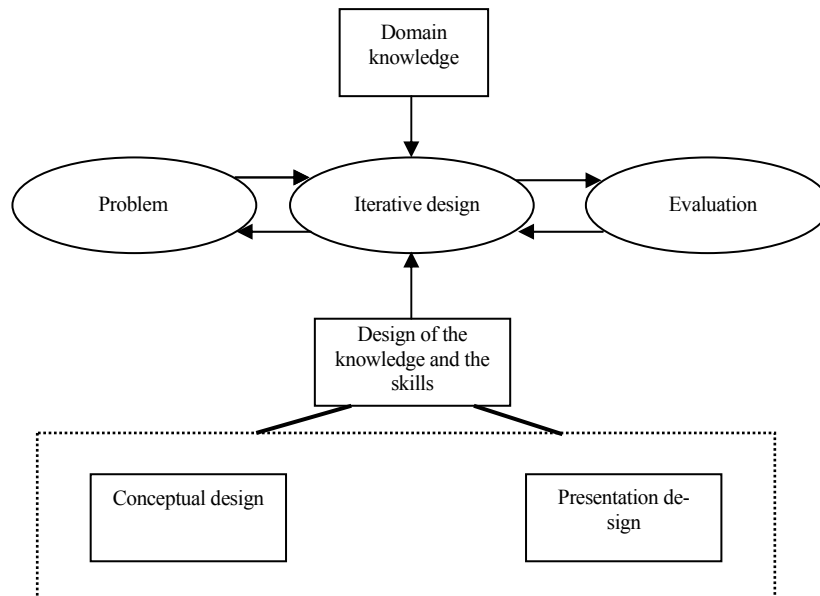
Figure 3.1: Schematics of the IMLE development

3. Multimedia Learning

The development of the multimedia learning depends mostly on the development of the information technology. Contemporary technological capabilities of the multimedia are in the true meaning of the word – amazing. In order to be able to successfully use the new technologies, it is necessary to know the basic principles of the learning well.

Learning is most efficient when it is interactive. Therefore, an interactive multimedia learning environment (IMLE) has to be created. Fig. 3.1 shows the schematics of the main components included in the IMLE development. The outer layers of the diagram represent the basic knowledge and skills that are incorporated in the system. They, on one hand, represent the knowledge of the multime-

dia design, and on the other hand, the knowledge from the subject that is being "taught".

The knowledge and the skills during the designing process are divided in two parts: conceptual design and the presentation design. The conceptual design includes the creation of a learning architecture. It consists of constructing interactive options for the student, consultations with experts and constructions of the knowledge in that field. The presentation design refers to the realization of the system, in which the screen positioning, the colors and the usage of individual media are of greatest importance.

The most important part of the system refers to the development of the multimedia project. The process is usually of an iterative character. The initial design represents a prototype of its author. Then, having received feedback that is analyzed with the experts, it is evaluated and upgraded. The development represents a spiral in which the design, the application and the evaluation are interwoven. In order to supplement the whole process, one takes into account the knowledge acquired through the most representative examples that will improve the work of the program.

4.   Multimedia Learning System In Computer Science

The multimedia learning system in Computer Science covers the whole educational program of the subject Computer Science in selected high schools in the Republic of Macedonia. Having in mind the postulates of the presentation design of the multimedia learning environments, an attempt has been made to present the lectures in a way which would create a positive learning atmosphere for the student. During the development of this multimedia learning system, we have taken into account its application in the teaching process and the evaluation of the students, that is to say, contemporary learning theories and the contemporary design approaches for this kind of learning environment have been taken into consideration.

The main emphasis of this chapter is put on the description of the procedure regarding the development of this educational software. It deals with the way the concept of the contents, design and the acquisition methods of multimedia elements are made. It also deals with the realization of the interaction with the user and the way of uniting all these elements as an entity.

4.1   Phases and procedures in the system development

Following the principles, the technological capabilities and the methodology previously described, the development of the multimedia system was realized in several phases and sub phases. They were realized in parallel or consecutively,

and also with some interconnections and overlapping. The subject group has been defined – high school students.

In general, the whole development can be divided in two phases:

- Phase I – preparation of the scenario and creation of the multimedia components
- Phase II – creation of an applicative solution, integration of the components in a functional entity

In Phase I, several activities which reflect on the concept of the system have been performed, and consequently the following principles should be adopted:

- Based on the experimental teaching program for the subject Computer Science in the high schools in the Republic of Macedonia, the contents to be studied have been identified.

- The general concept of every entity focuses on the identification of the problem and the need for content knowledge, the explanation of the solution, the presentation of the solution procedure, the presentation of the key screen and further explanation or illustration with a suitable multimedia form.

- As an illustration (example), for most of the procedures it is advisable to make a **presentation video**. The example being recorded should be simple. The list of presentation videos is made after the completion of the textual content.

- While giving explanation about the hardware **video sequences** are used. They have been recorded in order to present their appearance and integration in the computer. The list of videos and the scenario for each one of them are made after the textual contents.

- For further explanation of the principles according to which certain hardware components operate and in order to give further explanation about procedures that are difficult to grasp or are abstract, it is advisable to have **animations** with **sounds**(i.e. with recorded speech).

- **Photographs** of open hardware units should be used in the system. That will allow students to visually experience the principles of their operation.

- HTML documents, in which the connection of all multimedia forms will be realized, should be created. The HTML documents' appearance should not be determined. It should be class based and determined in runtime of the application. This will enable a dynamic and variable appearance which in turn should affect the students' interest.

- Possible interactions have been determined. These interactions, besides the general hierarchy and sequential navigation in the system, hyper textual connections of entities with similar content underline the usage of the user key word indexes, more important terms, contents etc. It is of great importance to also find and select the most interesting topics for the students. One should have an interactive approach towards the multimedia forms, and this interaction should mean having control over the process of progression of the multimedia forms.

- As part of the existing system, a new system should be built for independent testing of the students during the learning process, as well as for formal tests and evaluation.

- Design of a **data base** based on the data and the information obtained from the activities of Phase I.

Beside the determination of the concept, all the above mentioned activities have been realized in Phase I.

The development and creation of the solution for integration of the multimedia components realized in Phase I was executed through the following steps:

- The first step in the realization of the applicative solution is the definition and creation of the user interface of the application.

- By creating the applicative solution, all the elements have been integrated in one functional entity. In this way, the prototype is obtained and tested and eventually corrected. The solution is created in the program language Visual Basic.

- During the process of the creation of the **Setup** application self-installing executive applications have been created. They perform automatic installation of all the necessary software components for further use of the learning system application.

- One of the most important aspects during the creation of the multimedia system is the process of testing the functionality and correctness of the application solution. The testing consists of several phases, such as testing of the installation process and testing of the application on several hardware platforms and operating systems.

4.2   Learning system architecture

The multimedia learning system of the subject Computer Science is based on Web technology.

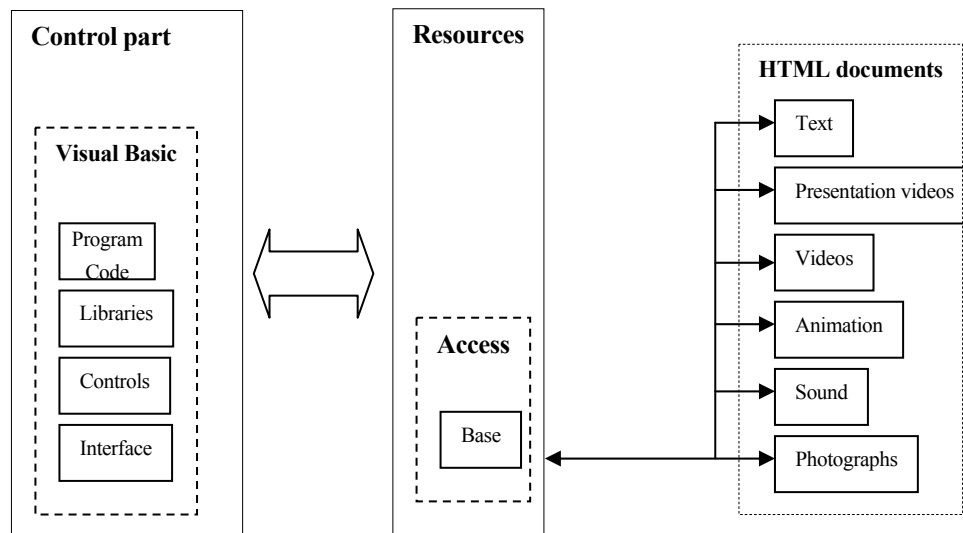The basic concept is shown in Fig. 4.1.

Figure 4.1: Learning system architecture

4.3   Index creation

The issue regarding the use of indexes as a special way of searching can be found in books that serve as a media for distribution of information. The use of indexes in computer systems dates back to the early beginnings of computer systems' usage. By using the indexes, one has direct access to the data. All one has to do is use a key word that is placed in some kind of order (i.e. alphabetical). This way of accessing the contents is implemented in the multimedia learning system.

A process that consists of several stages precedes the realization of the index system in the learning system:

- Determination of the key words that will enable access to the contents of the system;
- Finding out the contents by using key words.
- Linking the first two attributes in the data base.

The whole procedure is realized with the help of the service application DHTML Editor in similar way as the hyperlinks were added to the multimedia contents. By using the Tree control, all the HTML files have been analyzed. A selection is performed in each one of them, after finding out a significant term – key word or several words. After this, the right mouse button is used, and from the menu that appears, the 'Add Index' option is selected. By doing this, a connection is established between the key word and HTML file in which it is located. A program

code which in the Index table of the Informatika base adds a field in which it inserts the two attributes – the key (index) and the HTML file stand behind this process. Fig. 4.2. illustrates the principles of creation of the index base.
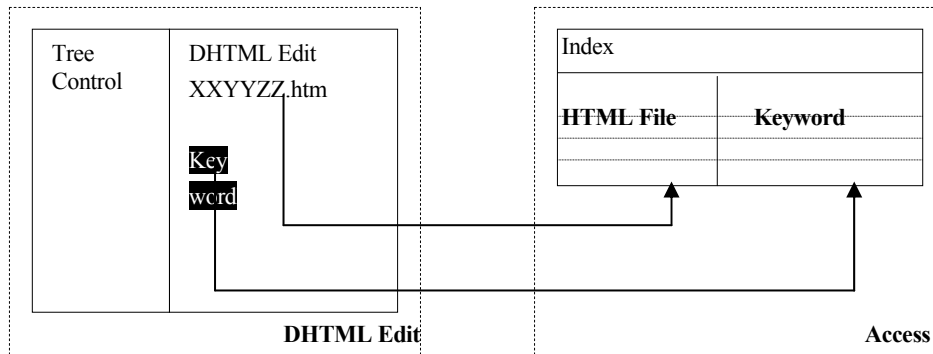

Figure 4.2: Index creation procedure

4.4   Testing and evaluation system

For wider range of users of the learning system, the basic criterion for defining what has been learnt would be the capability of the user to use the applications that are studied. In the case of the learning system for the subject Computer Science, there is a need for formal evaluation. Such evaluations are socially acceptable quantified values of the student's knowledge. Besides that, on one hand, the evaluation should determine if the goals of the learning process have been achieved, and on the other, it could represent proof of what is learned and which can be checked again.

In order to achieve these goals, the learning system itself has its own integrated system for testing and evaluation. In the Quiz table of the Informatika base there are 155 questions from all the lectures presented in the system. For each question in the Answers table 7 options are given and only one of them is correct. The options are more or less logical and similar to the correct answer. During the testing process, for the question being asked, 4 possible answers are offered, i.e. the correct one and 3 more which are incorrect. The probability for repetition of the provided answers is:

$$P_1 = \frac{1}{C_6^3} = \frac{1}{\frac{6!}{3! \cdot 3!}} = \frac{1}{20}$$

The fact that the order of the offered answers is accidental decreases the probability of identical repetition (same answers given in the same order). The probability for having such a case is:

$$P_2 = P_1 \cdot \frac{1}{P_4} = \frac{1}{20} \cdot \frac{1}{4!} = \frac{1}{480}$$

Testing can be interactive (done on the computer) or the test can be printed on paper. A second method can be applied in situations in which a larger group of students are to be examined (e.g. class), and when it is important that the questions be identical for every student.

The testing itself or the preparation process of the test begins by selecting the topics that will be tested and determining the number of questions that will be used to test each topic. Hence, the system limits the number of questions. The number of questions cannot be bigger than half of the total number of questions for each selected topic. This limitation provides protection from printing all possible questions.

After defining the topics and the number of questions for each topic, questions are selected at random and together with the possible answers they are placed into the table TmpQ in the base AlfaBit. The students' answers are placed in the table TmpAll. Then, depending on the type of the test (written or interactive), the questions appear on the screen or in a Word document in random order. If the testing is interactive, a report is generated. This report gives the correct and the incorrect responses and also states the duration of the test. If the testing is done in written form, a list of correct answers is prepared. The logics of generating the tests is presented on the diagram (Fig. 4.3).
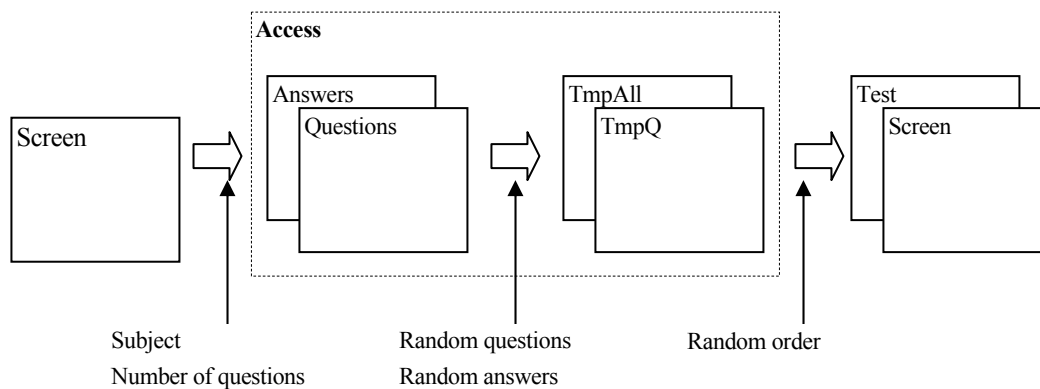

Figure 4.3: Test generation logic

During the learning process, students can interactively test themselves on each topic. The same sets of questions and answers are used, except that the number of questions is limited to 15% of the total number of questions for a certain topic.

4.5   Database

The data describing the educational contents are stored in the appropriate multimedia files. They are integrated in artifacts in a HTML document form and as such are saved into different files. However, in order to implement the system, it is necessary to have data of different value and form. I am talking about data that is used for the functioning of the system. They refer to, for e.g., the relation among the titles and artifacts and the names of the HTML files in which the appropriate content is set, to the questions and answers from the testing system, etc.

As a most appropriate way for storing and using such data, an Access base has been chosen due to the following reasons:

- Access base is relational, and as such offers more advantages: the possibility for creating relations among tables of the base, securing the redundancy of the data that enables easy manipulation with the base;

- Access base uses indexing as a way of having direct access to the data in the tables;

- Access base is well integrated and has good communication with the program language Visual Basic;

- all data are integrated in one common file which is copied during the system installation phase.

Based on the previously presented facts, during the construction of the learning system, the use of Access database is established. All the information of crucial importance and some temporary data is stored in this database. A functional analysis of all information has been done in the phase of projecting the database. Several tables have been defined. According to the aspect of their content and the usage of the system, they can be divided into three groups: navigational tables, testing system tables and tables for archived data.

4.6   User interface

The realization of the user interface has two phases:

- analysis of the system from the aspect of its function, by which all necessary elements for the user interaction with application are defined. The aim of this analysis is to obtain maximal usage of the current information. Based on this analysis, elements of user interface and their layout are defined. When these elements have been defined, a test of the functionality of the interface is administered.

- The second phase begins when the functionality of the user interface has been tested and when the results have been collected. In this phase the

design and the disposal of the interface elements is made. In this way, one defines the appearance of the application.

From the several available models for the system's base, the system of asymmetric division of the interface has been chosen. This division is typical and familiar in modern applications (ex. MS Encarta, Windows Explorer, etc.) and in some web presentations. The concept of the interface is shown on the Fig. 4.4.

Contol zone 1

Navigation zone

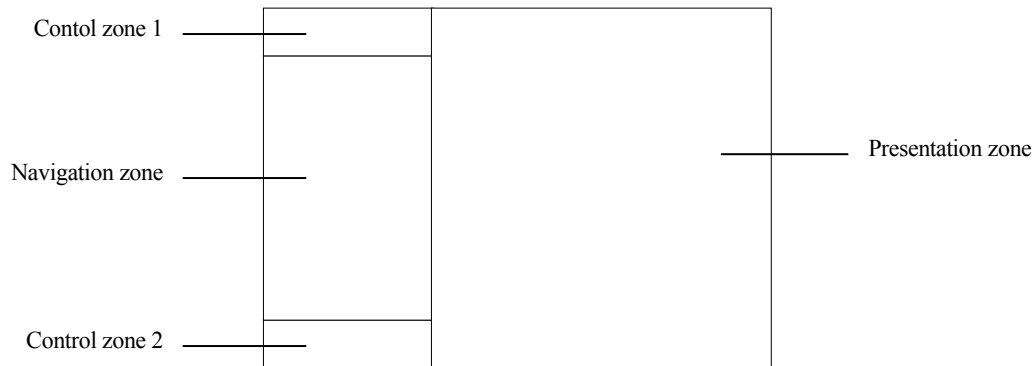Presentation zone

Control zone 2

Figure 4.4: Concept of interface

In different situations, different elements are shown on the screen. The display of these elements, as well as the common behavior of the system is controlled by a program code in Visual Basic. Defining the elements on the user interface alludes defining the background, the interaction buttons and other additional elements.

Giving the final look of the interface in runtime goes through the following process:

1. display of the background
2. display of the interaction buttons
3. display of the content of the system
4. display of the additional elements depending on the content that is presented and the user actions.

The background is displayed by activating the system. It builds up with the interaction buttons. The rest of the elements, for example, the background for displaying animations, appear and hide depending on the need.

4.7   Applicative solution

The multimedia application is a product of a combination of several technologies. The basic shell has been developed in Visual Basic, whereas the written part is made in Microsoft Internet Controls (WEB Browser control). For the ne-

cessity of this application several ActiveX controls have been made, some of which have been made in MS Visual Basic, and some in MS Visual C++.

There are 2 types of navigation. The first one is the so-called TAB control. It serves for choosing the themes from the content. The second one is subclassed Tree View control (SubTree.ocx) and is control based on 'MS Common Control Tree View' control to which some features (such as background picture, different colors of text, etc.) are added.

The whole application with DAO (Data Access Object) leads to a database that consists of several tables. The most important table is the table 'Topics', which incorporates the whole content displayed with TopicID, Version, Title, HTML File. The Tree View control uses the same table to extract information.

In the database there is a table (Index) that incorporates all indexes. In this way, one can search the content. The Index table contains IndexID, TopicID, Index and BookmarkID (the last entity serves for the application to know in what part of the text it should position itself).

4.8   Installation procedure

The learning system for the subject Computer Science in the high schools has been produced in the form of a CD ROM. During the designing process of this system and its components it was taken into account that the total memory space of the system does not exceed the capacity of the standard CD-ROM. At certain moments, such an approach lead toward limitations in the creation of the multimedia components integrated in the system – especially video files that take up a lot of space.

To use the CD-ROM and to enable its usage it is important to install it in the computer. In order to make the installation process easier, two applications with auto-installation procedures that are recorded on the CD ROM have been made. They are the following:

- Setup application in which auto-install executive applications are created. They conduct an automatic detection and installation of all the necessary software components in order for the system to be used.

- additional application. Once the CD ROM is inserted, this additional application helps to automatically activate the Setup application if it is the first time to run the CD ROM. Another way is the activation of the application if the process of installation is finished (AutoRun).

Both applications are made with the program Wise Installer 8.1. The application AutoRun activates itself by inserting the CD ROM in the computer's drive. It consists of several procedures that provoke action. The most important component is the detection of the installation of the learning system on the computer. If

the system is already installed, it will start functioning. On the other hand, if the system is not installed, the Setup procedure is called for in order to install the system.

4.9   Testing the application solution

- One of the most important aspects in the production of the multimedia system is the process of testing its functionality and correctness of the application solution. Testing covers several phases:
- testing the process of installation;
- testing the application on several hardware platforms and on all operating systems in which the application will be used;
- testing the functionality

During the production of the learning system a test was performed based on the first three phases (formative judgment). While testing, some faults and mistakes were identified, and they were removed. After receiving positive results, the system was distributed to individuals and institutions.

All high schools in the Republic of Macedonia were included in the testing. During the school year of 2000/01 all high schools received a free sample of the system (i.e. of the CD ROM). Every school had a task to test all planned elements. According to the received feedback, there was no problem in the installation process and the functioning of the application on different platforms. This means that the system functions well on computers with operating systems Windows versions 95, 98, NT and 2000. The few reported mistakes dealt with the incorrect functioning on certain hyperlinks due to the process of connecting a huge amount of files. Every reported mistake was corrected.

5.   Analysis of the learning system

As previously mentioned, this learning system is similar to an electronic book. To be more precise, the system for multimedia learning (Informatika) is an electronic Handbook. Its interactivity is close to an electronic encyclopedia, while the documents are connect with hypertext links.

The content of the system has a hierarchic structure which originates from the formal analysis of the Computer Science field. The thing that is done for the analysis of the material and the knowledge that the student has to acquire is in the spirit of Gagnè's theory of instructional design. This analysis of the knowledge that students need to possess for the subject Computer Science initiated the hierarchical structure of the material. Moreover, the necessity of the hierarchical organization of the material can be seen in the fact that one of the main aims of the

system is to present the whole content that is included in the curriculum for the subject Computer Science in multimedia form. Nevertheless, using the opportunity to choose themes at random order, the instructor could freely select teaching units. This could also be done by the students themselves. All this means that the content is organized as such that it has a hierarchical organization which can be broken. This is due to the fact that it allows the instructor the possibility to create the order of the teaching units.

In relation to the possibilities that this system offers to the users for interaction, it is based on a free approach (browsing). The user can freely access every single teaching unit. That means that there is no certain application which will control and lead the user through the content. This is a direct consequence from the concept of this multimedia system, which is produced as an electronic book. Within the teaching units, there are different types of multimedia elements which contribute to the interactivity with the user. Due to the fact that the interaction with the student is based mainly on reviewing the material, that means that there is initiation of the construction of student's knowledge. This gives the student freedom to select his own route in the computer's based learning system. This is in accordance with the constructivist tradition according to which knowledge is constructed by the individual in interaction with the surroundings.

This software can be classified as teacher-type computer, mentioned above. That is because students, besides having the opportunity to explore the content of the system, do not have access to freely create new contents or generate the problems on their own.

From the aspect of classification by the educational scheme, Computer Science cannot be classified strictly into one type. The completed software has instructional features due to the structuring of the content. At the same time, the software has features of exploration, because the user can independently explore the content of the system.

And finally, the main aim for the creation of this system is for the system to be used as a resource that will supplement the conventional teaching method. This is partially in accordance with the mentioned theory for essential learning, according to which it is important to have a personal involvement of the student. This theory says that assisting the learning process includes organization and creation of available resources for learning. This is what this CD-ROM is all about.

6. Conclusion

The spectrum of the learning theories is fairly big and it consists of many approaches or methods of explanation of the way people learn. Mainly these theories either belong to the behaviorist or to the constructive concept, or they are

theories in which the emphasis is not on learning. However, their implications directly refer to this issue. The behaviorist and constructive concepts are bipolar in many ways – the main difference of both concepts lays in the assumption that deals with the way of acquiring knowledge. According to the behaviorist concept, knowledge exists independently of the student, and this provokes the concept of imposed instruction. On the other hand, the constructive concept assumes that every single person constructs their own knowledge in interaction with the environment. Thus, this initiates the concept of giving an opportunity to the student to construct his own knowledge through the process of interaction with the environment, throughout exploring and problem solving.

These two concepts have their own implications in the design techniques of the multimedia environment for learning. When talking about the conceptual design of these environments, Gagne's instructional design has proved to be suitable for the computer and this in turn is compatible with the behaviorism. At the same time there is a constructivist conceptual design in which, as a main principle, besides the individual's construction of knowledge by the student, one also has to take into account the social context in the education.

Nevertheless, the realistic solutions for the creation of the multimedia environment for learning are not black and white- in some segments they are close to constructivism, but in the others to the behaviorism. Therefore, the designer of the multimedia environments for learning can choose from a large amount of options in the segments of structuring the content, interactions with the user and the context.

The emphasis in this study has been put on the created multimedia system for learning for the subject Computer Science in selected high schools in the Republic of Macedonia. This concept is similar to an electronic book, i.e. electronic hypertext based Handbook with interactivity similar to an encyclopedia. When looking at the content, the system has a hierarchical structure which has been derived from the formal analysis of the Computer Science curriculum. This also comes as a result of one of the main aims of the system - to present the whole content that is covered by the teaching program for the subject Computer Science in multimedia form. Based on the capabilities that this system offers to the users in interaction, the users have a free approach (browsing). There is no application that would determine the route of the user through the content. In the teaching units there are different types of multimedia elements that allow interactivity with the users. In fact, by creating this system, we have tried to show that the material can be laid out in an attractive way and this would cause students to feel positive about learning. The fact that the interactions with the student are based on reviewing the learning material, the construction of knowledge by the student is initiated. This is compatible with the constructivist tradition, according to

which the knowledge is constructed by the person himself in interaction with the surroundings.

Finally, the main idea that lead to the creation of this system was for the system to be used as a resource that will supplement the conventional teaching method. By making such resources available for learning, one provokes the personal involvement of the student and his control over the acquiring process. This, in turn, is in accordance with the theories for learning from the constructivist tradition.

7.   References

1. Belkin, G. S. and Gray, J. L. (1977), Educational Psychology: An Introduction. Dubuque Iowa: Wm. C. Brown Company Publishers.

2. Skinner, B. F. (1968), The Technology of Teaching. New York: Meredith Corporation.

3. Piaget, J. (1970), The Science of Education and the Psychology of the Child,NY: Grossman.

4. Papert, S. (1993), The Children's Machine: Rethinking School in the Age of the Computer,New York: Basic Books, a division of HarperCollins Publishers.

5. Tapscott, D. (1998), Growing Up Digital: The Rise of the Net Generation. New York: Mc Graw Hill.

6. Gagné, R., Briggs, L. and Wager, W. (1992). Principles of Instructional Design (4th Ed.). Fort Worth, TX: HBJ College Publishers.

7. Boyle T. and Margetts S. (1992) Pascal by active learning using the CORE approach. D.P. Publishing.

8. Boyle T. and Davies M. (1996) Hypermedia environments for learning to program. In P. Brusilovsky, P. Kommers and N. Streitz (eds) Multimedia, hypermedia and virtual reality. LNCS 1077. Springer.