CONCEPT MAPPING IN INSTRUCTIONAL DESIGN OF EDUCATIONAL SOFTWARE

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Abstract. *This article emphasizes the application of the map technique concept in the first phase of instruction design of computer software. The main aim of this paper is to identify criteria to serve as guidelines in outlining the methods used in concept mapping.*

Keywords: *instructional design, educational software, concept map technique, oriented graph, learning theories.*

Introduction

The Adaptive Hypermedia (AH) and Intelligent Tutoring Systems (ITS) are two of the most used adaptive education systems on the WEB. The AH systems are focused on non-linear and adaptable structures of the educational materials [1]. ITS provides a user-oriented design and much more pedagogical knowledge implemented into the system. But, in the planning phase of education software the author must understand how the structure of students' knowledge will build the course. This phase requires determination of concepts expected to build a student - centered learning process. Typically, using the techniques of concept mapping, mind mapping or ontology structures solves the problem of the number of concepts and tries to solve the problem of power of links between concepts. These problems were analysed from a technological point of view by Netusil A.B., Nichitin, 1969 [2], Zaiteva, 1989[3], Zaiteva et all, 2003[4] etc. But the power of concepts depends not only on the correlation between notions (paragraphs, texts etc.), but also on the correct determination of the core concept. This idea is very important for instructional design of educational software, because it solves the problem of forming the knowledge structure. This paper focuses on problems in determining the core concept in e-manual for study Logics and e-manual for study Mathematics. This analysis leads us to understand that core concept is the essential element that can be used as a generator of structure and that structure increases in module and then from one module to another. The arguments in favor of the core concept can be found in scientific literature, for example: in the theory of functional context, proposed by Allen, 2002, [5]; the overlay model of Beck, 1996[6]; Cognitive Flexibility Theory[7]. Other arguments can be found in the proposed principles of instruction: the most general ideas of a subject should be presented first [8]; instruction must be structured so that it can be easily grasped by the student [9]; cognitive structures are patterns of physical or mental action and cognitive structures change through the processes of adaptation: assimilation and accommodation [10] etc.

The instructional design

The concept of *instructional design* is analysed as a process, a discipline, a science and a reality [11]. The scientific domain of instructional design includes interdisciplinary research in education -psychology – communication and educational technology. This point of view shows the efficiency of a systemic approach in comprehension of notion. So, the role of educational research in the instructional design of educational software is to find the best models in developing the effective training, learning and assessment strategies; the role of

research in psychology is to find the best ways of forming knowledge, abilities and competences; the role of communication is to determine the rules in message design. Educational technology has had a special role that determines the efficiency of instructional process output (Figure 1).
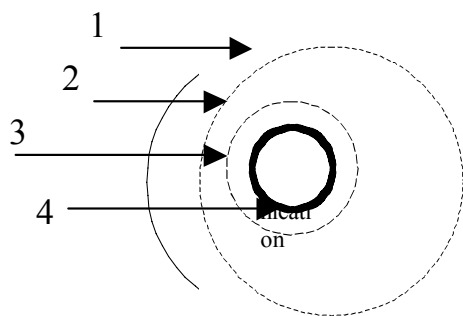

Figure 1. Systemic approach in terminological aspects of instructional design represented by Euler circle.

1-education, 2-psyhology, 3-educational technology, 4-instructional design.

At least 40 instructional design models are known and these models share the same underlying process of Analysis, Design, Development, Implementation and Evaluation of educational software. All models include some aspects of educational, psychological, communicational and educational technology research.

The father of instructional design is considered to be Gagne, who linked learner analysis to the design and development of instruction and served as an approach whereby the results of a learner's placement test are used to plan learner-specific instruction, but the father of instructional design theory is Reigeluth [12], who describes the characteristics of an instructional-design theory as oriented toward design; as focused on the means to attain goals for learning and development, on the identification of methods of instruction as a way to support instruction, and on the situations in which those methods should and should not be used.

Concept mapping

The main role of Instructional Design is to increase the quality of instruction. This aim can be solved by answering two main didactical questions: What should we teach? and How can

it be taught?

We try to find answers to these questions in studying the role of oriented graphs. One such technique is the technique of concept mapping as a way to organize the information proposed for learning. This way has been known as a formal or semi-formal diagramming technique [13] or a technique for representing knowledge in graphs [14, 15]. Professor Novak developed the concept of mapping technique at Cornell University in the 1960s. This work was based on the theories of David Ausubell, who stressed the importance of prior knowledge in being able to learn about new concepts. Another technique, Mind Mapping, developed by Buzan, described mind maps as consisting of: "*central word or concept, around the central word you draw the 5 to 10 main ideas that relate to that word. You then take each of those child words and again draw the 5 to 10 main ideas that relate to each of those words* [16, 17]. This idea can be used in instructional design of educational software. The core concept applied in instruction design will effectively build the knowledge structure. The problem of using the mind mapping in instructional design is not so easy and depends on the initial structure of instructional material. For example the instructional material can be structured in a traditional manual that can serve as the base for building the e-manual or instructional material that has been planned in course curricula.

In our work we analyse both possibilities.

The matrices of interactivity

The main problems in using the mind mapping techniques in instructional design of educational software are 1) to determine the core concept around which will be built the knowledge map and 2) to find the concepts that can be associated with the core concept. These problems can be solved through applying the matrices of interactivity in which has been included the power of links.

The matrices serve the base for oriented graph G presented by:

$$(A(G)ij) = \begin{cases} 1 & \text{for } i \text{ and } j \text{ adiacente} \\ 0 & \text{in contrar case} \end{cases}$$

The method of oriented graph is similar to concept mapping, so we can use the matrices in building the knowledge structure. The power of links determines the interdependence between concepts [3, 4]. In Zaiteva, 1986, the number 1 is shown as determining the links' power between two themes in which for study is necessary to have general knowledge about the second theme; the number 2 is used for links between themes the study of which is important to apply the concepts from the second theme; 3 is used in cases of correlation between the difficult to understand new concepts (or rarely used concepts) and prior knowledge; 4 is the strongest link and shows the impossibility of studying new concepts before understanding the prior concepts.

According to the Zaiteva the matrices can be represented in the form of a table. The vertical and horizontal lines determine the number of chapters, themes etc. The dimensions of matrices depend on the structure of the educational software instructional design.

The filling of matrices have been completed in the following stages:

1. Elaboration of the list of software chapters and the lists of themes that are expected to be included in each chapter.

2. Elaboration of matrices of interactivity for all chapters and themes. In this case the matrices of interactivity have a square form, are bi-directional and the number of lines depend on the number of themes in the chapter. The number of chapters is written on the exterior and the number of themes on the interior of the horizontal and the vertical positions.

3. The horizontal filling of the matrices means that if the number of the theme coincides with the number of the theme in the vertical line, the cell will be filled. For example if for studying the theme 1.4 we need the concepts from 1.1 or 1.2 or 1.3 we will need to complete the respective cells, but the value will be find according to the Zaiteva principles.

So, the filling of the matrices of the interactivity is done as following: the element of matrices that can be found at the intersection between *i-line* and *j-line* is equal with 0, if in the study of themes from *i –line* the previous knowledge is

not necessary and is equal with K, if in the study of the current theme (paragraph, concept etc.) the previous knowledge is necessary. In this case the K = 1, 2, 3 or 4.

On the other hand, according to the learning theories correctly designing material for instruction requires that each concept must correlate with all others. In practice, it is possible to solve this problem by using two variants. In the first case the matrices of interactivity will be developed according to the instructional material that will be used in electronic manual. So, in the analysis phase of the design of the e-manual *LOGICS* we determine the base notion (**al form**) and then build the matrices of interactivity for all modules, but consider the power of links not less than the value of three. On the contrary, in the analysis phase of the electronic manual *Mathematics* we made the curricula analyses and built the matrices according to Zaiteva's principles. As a result we developed the following stages:

1. Curricula analyses where we determined and selected the new concepts used in the study of mathematics according to the curricula;

2. Numbered the new concepts using the following form:

Table1. The dependence between the concepts and the notations

The concepts	The notations
5 Mathematics V	The name of the form
5.1 natural numbers	The name of the chapter
5.1.1 formation of the natural numbers	The name of the theme
5.1.1.1 Arabic numbers	
5.1.1.2 decimal system	
5.1.1.3 ordins	The name of the notions
5.1.1.4 classes	
5.1.1.5 positional writing	

3. Matrices elaboration for all chapters including the power of the patterns

Table1 Matrices for themes 1.1 –1.3 (V form)

Nr. Theme	I.1	I.2	I.3	Correlation between themes
I.1	--			(4)5.1.15; 6.1.3; 6.3.2 (2) 5.1.14
I.2	4	--		(4)5.1.8; 5.1.16; 6.3.1; 6.3.2; 6.3.3;6.3.4; (2)5.1.14;5.1.18;5.1.21;5.1.23; 5.2.216.3.5; 6.3.6
I.3	4	4	--	(4)6.4.1;;6.4.2;6.4.3; (2)5.2.1; 5.2.6;6.2.16.4.4;

One interesting result was that by studying the number of new concepts in the initial curricula context and in the final matrices, we found a difference between 46 new concepts and 103 proposed concepts according to the curricula.

The role of matrices in building the graph of knowledge

The next stage was in applying the matrices of interactivity in the elaboration of the graph of knowledge with the central concept. Firstly, Jose Antolio Cascales proposed the solution for the problem of determination of the central concept in a chemistry course. He proposed a hierarchy of concepts in level I, II etc., with one concept being placed as the central concept. In our study we use two variants. In one case (e-manual in s) as postulated in the previous section, we built the graph of knowledge using the base concept, but in the other case we tried to determine the base concept through curricula analysis. So, for the first case for the first theme of the module we have the following model:
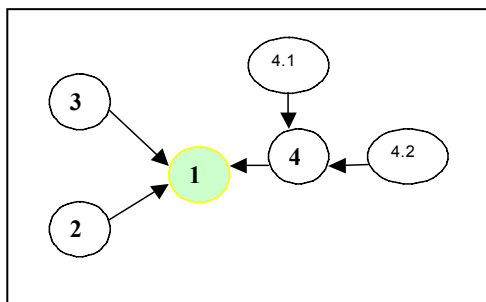
:

Figure 1. The concept map for first theme of e-manual Logics
1 – the base concept (logical form)
2 – the concept
3-- logical proposition
4 -- judgment
4.1 premise and 4.2 conclusion

Later, in developing the design of the next theme, we added the concept according to the proposed structure. So, at the second lesson will be developed the second concept according to the following structure:
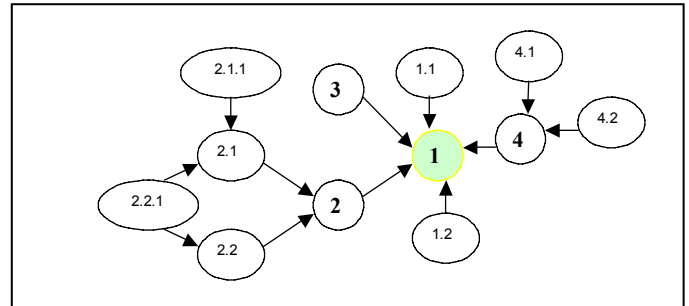

Figure 2. The concept map for second theme of e-manual Logics.

The structure will increase and will be more complex, but the concepts are dependent on each other. For example, in the picture above we can see the dependence between the central concept and three modules and between structures' concepts. This model permits the elaboration of the structure of the electronic manual for the study of LOGICs based on power complex structure with functional instructional context.
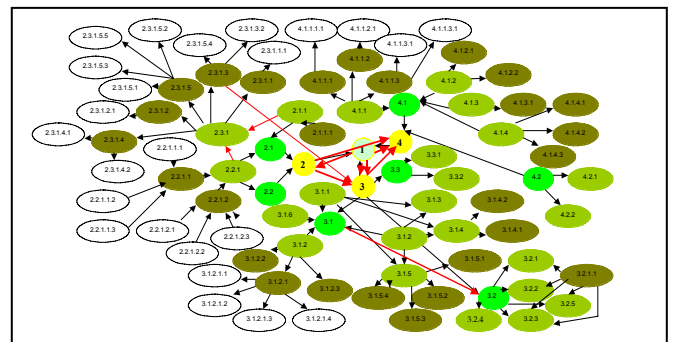

Figure 3. The concept map in e-manual Logics.

The matrices of interactivity were built in the same way. The concepts unnecessary for studying the new instructional context were eliminated.

The next solution was proposed for the electronic manual for the study of mathematics.

In this case we built the concept map as the next stage after developing the final matrices of interactivity. Then we built the concept map for all themes, joined the themes in chapters, the chapters in modules and elaborated the final concept map or graph of knowledge. We concluded that to develop the graph of knowledge consisting from unitary structure it is necessary to join all the maps in a complex structure. Also, we observed that it is impossible to build this structure without the precise elaboration of the general matrices of interactivity.

The analyzing of concept map structure shows 4 base notions:

1.Numbers

2. Sets

3.Functions

4. Algebraically expressions.

These concepts serve as the name of the modules. The proposed model permits us to determine the educational software structure that includes the 4 base concepts with the role of modules. We concluded 4 modules; module 1 – from 3 chapters; module 2 – from 5 chapters; module 3 – from 1 chapter and module 4 – from 4 chapters form that the educational software for Mathematics.

Variables influencing the use of concept map in instructional design

In this section, drawing on the above examples, we discuss some of the variables affecting the applied concept map in instructional design, and we identify their role in the Analysis stage.

Generally speaking we could identify two kinds of variables:

1.   Variables related to the curricula development context
2.   Variables related to the aim of the electronic manual as educational software

In principle, the latter should play a role in the building of the instructional context when the author of the manual has a clearly determined aim and objectives, but in this case we must provide the concept map tool for drawing the instructional structure. In the first case the process requires an algorithm for building the instructional context based on curricula analyses. Moreover, the distinction proposed is hardly ever clear-cut and it is evident that variables of the two kinds are strongly linked to each other.

Instructional design is based, first of all, on the systems approach that involves setting goals and objectives, analyzing resources, devising a plan of action and continuously evaluating/modifying the program. On the other hand, the instructional designer must develop a complex structure in students' knowledge and for this realization he can analyse the instructional context using concept maps and form a structure between powerfully linked concepts that will be used for instruction. Most importantly, all proposed variables provide better results when it comes to building a graph of knowledge.

Conclusions

The instructional design of educational software cannot come down to the mechanical applications of the principles or concepts or pre-set algorithms. In our case we analyse the model of applying the concept mapping technique in the Analysis stage of instructional design of educational software for Logics and Mathematics. However, the systematization and semiformal structures of the instructional context can be of significant support for educational software designers as they allow for using the matrices of interactivities and concept map techniques to analyse the instructional context or for building the instructional context beginning from a core concept.

This article can be considered as a starting point for research activities, which might develop:

1.   the application of concept map techniques in analysing the instructional context

at the first stage of development of educational software.

2. the elaboration of algorithms for analysing instructional structures.

3. the investigation of analogies between instructional context analysis based on relationships between curricula and structure building and between concept maps and structure.

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