The Skills-Space Model for Educational Content Representation as a Software Realization

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Abstract. Educational contents feature the ability to be explored in alternative dimensions of skills where even the rudimentary knowledge of the other dimensions contributes and/or are prerequisite for the better understanding of another. The representation model that contemplates this orthogonal exploration is the Skills-Space Model (SSM). This paper presents the SSM model and its realization in the form of a web software, called MEHRECE. The paper starts by reviewing Educational Contents Representations and situate SSM among them. This implementation has shown how SSM contributes to emphasize the relationship between the content and its structure (meta-knowledge).

Keywords: Distance Learning, Skills Space Model, Educational Contents Representations

1. Introduction

Nowadays, Distance Learning (DL) is in focus on the global scenario. Its ability to spread knowledge provided a considerable increase in the search for such courses as well as in investments, allowing a steady increase in the quality of available systems. To achieve efficiency in this type of education it is necessary for the participants, educators and learners, to interact regardless of space or time (Borges et. al., 2003:2-3). Entering and manipulating contents into DL courses is not an easy task. Murray (1999:101) suggests the use of “authoring tools”, to facilitate the process, aiming to receive from the educator, information in an organized way and with pre-defined relationships or dependencies among the important content.

Mayorga et. al. (2002:2-3) states that developing educational materials that allow some interactivity with the apprentices is the best way to attract the attention of participants in the Teaching-Learning Process (TLP) for programmatic content. The author also points out that the technology by itself, can not achieve this goal, but need to be based on interactive models to facilitate human understanding.

In addition, a model adopted for the Educational Content Representation
(ECR) need to be appropriate to the target subject since different areas of human knowledge and different forms of presentation have features that must be taken into consideration. And, it is not sufficient to represent the educational content but one must also promote their understanding and visualization. Therefore, the search for ECR models becomes a prospect to discover alternative ways to share and organize educational materials and the need of a thorough comparison of existing models and their features.

The main focus of this work is to identify an alternative model for the representation of educational content suitable for a technical discipline, in order to facilitate not only the TLP but also the authorship of a DL course.

2. Educational Content Representation (ECR)

In order to identify the area in which this research is applied, it is important to emphasize that there are mechanisms for the representation of knowledge, structures for representation of data and models concerning the representation of contents, since these kinds of information are treated differently in the computer system. Thus, one can say for example that:

- For the representation of data, the structures that are best known are Stacks, Lists, Queues, Trees, Graphs and Matrices;
- To represent content and use them in E-Learning Environments (EE), ECR models apply, which will be discussed in depth in this article, and the following can be highlighted: Hierarchical Model, Conceptual Maps, Topic Maps, Conceptual Graphs and Skills Space Model.
- Frames, Expert Systems and Production Rules are mechanisms to represent knowledge that are linked directly to the reasoning process and therefore used in the field of artificial intelligence;

It has already been said that data does not depend on the user, content is objective but its meaning is subjective and user dependent while knowledge is completely subjective because everyone has a different perspective on the same thing (Setzer, 2001).

In the following sections, different approaches to deal with educational “content” representation will be presented. Content is considered the bridge between data and knowledge, therefore the main focus of EE.

2.1. Hierarchical Model

The Hierarchical Model was the first representation model, according to Rodriguez and Nobre (2002:7). The philosophical principle that led its development is the fact that all real-life objects are somehow hierarchical in nature. It looks like an upside down tree formed by “branches” and "leaves".

Basically the hierarchical model is defined as being divided into levels, where each level may have several sub-levels (called sub-trees or “son”), but each sub-
level has only one direct and higher level (called “father”). There is not a rigid methodology to build up the contents’ structure, which requires from an educator an abstraction ability to divide the content in a way to achieve levels s/he requires to represent “basic and advanced”, or “difficult and easy” or, “simple and complex” which is not considered a difficult task. On the contrary, it is an easy task once it is left completely to the educators’ discretion.

It served as the basis for all following models and it should be noticed that the hierarchical model does not require that sub-levels (sons) have their higher levels (father) as prerequisites, or the other way around. It only shows the concepts in order of abstraction, in the way the educator see fit for the target audience.

2.2. Conceptual Maps

The representation of educational content in the form of Conceptual Maps (CM) is based on making it explicit the relationship between the concepts (Moreira and Buchweitz, 1993:25). CM can be defined as directed and acyclic graphs, or even that not only store information but also the relationship between them in terms of a graph. If one takes the a hierarchical model to compare it can be said that there are more inclusive concepts at the top, subordinated intermediaries and more specifics at the bottom.

![Figure 1 – A Conceptual Map on the Dengue Disease (Source: LARVA, 2006).](image-url)

The application of CM has wide coverage and one of its main features is flexibility because it is easily adapted to the educator’s area of interest. There is no degree of importance implied for contents on the same level. Each item on the map may present unstructured information. Through its visual capacity, one can gather the structure of the concepts in order to clarify the relationship between the contents which stimulates learning. Nevertheless, its ability to zoom in in any
direction and the large number of possible connections may turn the map diffuse and eventually harming contents understanding by apprentices (Larocca, 2002:29).

The visual presentation of a CM is a scattered tree, while the textual presentation can be presented similarly to the hierarchical model. In addition there is not a unique way to construct a MC neither a standard on the presentation but they all look like Figure 1 which pictures information on the Dengue Disease.

The CM is a diagram that shows the relationship between the concepts, according to a given hierarchical structure. In Figure 1, each item is represented by a rectangle, which are related by labeled connections. Below each rectangle, there is an icon that display details which can be a text or a picture on the subject.

### 2.3. Topic Maps

Topic Maps (TM) were published as a ISO/IEC 13250-Topic Navigation Maps standard. It is a standardized way for knowledge exchanging, with emphasis on the traceability of information. Its representation is made flexible due to its division into layers and the use of three different components known as Topic, Association and Occurrence (TAO) (Moore and Pepper, 2004: 6-7): A **Topic** is a resource that is represented in computational terms and may not necessarily describes something of the real world, which means it can be anything regardless of their existence or having some feature in which one want to represent facts. Topics may be typified; **Association**: indicates relationship between topics which are directly linked, and; **Occurrence** means that there are one or more resources relevant to a particular Topic. TM can represent semi-structured data through XML, that is, its visual presentation can be graphic or textual.

Garrido and Tramullas (2004:4) asserted that there are not many differences between the Conceptual Maps and Topic Maps on the pragmatical side, saying that it is even possible to represent a CM using a TM. The advantage in using TM however would be ability to store and share information in a standard format that allows traceability and repeated use.

![Figure 2 – Layers of a Topic Map (Source: AHMED and MOORE, 1999:6)](image-url)
Figure 2 presents three distinct Topics (see the circles), associated with one another (notice the rectangles) and a dotted line that divides the space of topics and the space of resources (document icons), which are the information on each Topic, respectively. It can be noticed that occurrences are responsible for interlinking the layers of Topics to their resources.

2.4. Conceptual Graphs

A complete definition of Conceptual Graphs (CG) is given by Cyre (1997): "A conceptual graph is a two-sided, finite and connected diagram consisting of a set of labeled concept knots and a set of labeled relationship knots." A conceptual graph is a formalism that includes the features for modeling the semantics of natural language, being formed by two types of segments: Concepts and Relationships. For the preparation of a CG it is therefore necessary to form the concepts and establish relationships that interrelate them.

Through CG it is possible to represent contents in a “logically precise format that humans can understand and computers can interpret” (Sowa, 2004:5). Its presentation can also be graphical or textual.

Figure 3 shows an example of CG, where the concepts are arranged within the rectangles and are interconnected through Relations. The concepts are "Andrew" and "Information Technology". The links are arranged within ellipses, in this case “is studying”. In a CG it is only allowed to link concepts using the given relations (Rincon et. al., 2004:6).

![Figure 3](image)

Figure 3 – A Simple Conceptual Graph (Source: RINCON et. al, 2004:6).

2.5. Skills Space Model (SSM)

The primary idea behind the Skills Space Model relates to the fact that knowledge goes ever specialized as it evolves. One can understand this point when it comes to a content isolated from other factors. But when one considers the relationship between various "dimensions" of knowledge, the content becomes more difficult to structure.

To understand the SSM, it is essential to understand the following terms (Hounsell et al., 2005:1648):

- **Dimensions of Skills**: are the various skills (knowledges) to be gathered by the apprentice;
- **Orthogonal Dimensions of Skills**: the orthogonality indicates that a certain dimension can be constructed regardless the others;
- **Degree of a Skill**: is the partition of the dimension of skills in finite items, so
that a lower degree indicates a easier and elementary skill and higher degrees a more complex and difficult skill.

Figure 4 – Skills Space Model for the Chess Game.

- **Atoms of Knowledge**: Is the content on the intersection of all dimensions of skills for each given degree of skill;
- **Prerequisite**: a fundamental underlying concept indicating the necessary sequence of atoms for the best understanding of a following one;
- **Neighbor**: is an atom of knowledge that is in the geographical vicinity of another. The neighbors are divided into two types: “visited” and “non visited”. Those that have already been visited represent contents that have been "won" that is, they have already been assessed by the educator and therefore certificated as perceived by apprentice; and those who were visited, but not yet “won”;
- **Immediate Neighbors**: is a non visited neighbor of an atom of knowledge that is enabled to be visited by the apprentice because he has won the prerequisites in all dimensions of skills.

Thus, Hounsell and colleagues (2005:1649) define a Skills Space as a structural representation of contents that includes various orthogonal dimensions of skills where each atom of knowledge keeps an individual and intrinsic set of prerequisites organized as a matrix and allowing the free exploration of immediate neighbors.

Figure 4, shows the skills space for the static properties of chess game which is considered of technical nature like a programming language for they both use the
characterization of the involved entities (elements) and their rules of usage (functioning) make up the cognitive process used to solve (win the game or build a program) with certain specific strategies or tactics (intelligence).

3. Skills Space Model as a computer software

A software named MEHRECE implements the Skills-Space Model in the form of the first e-learning tool made entirely in JOOMLA (2005) in Brazil. JOOMLA is a software library that allows rapid development of a comprehensive e-learning environment features (communication, administration and, so on) since these elements are easily configurable into the application through the use of free components developed for JOOMLA.

![Figure 5 - Structuring and Author of course in MEHRECE.](image)

The main screens of MEHRECE are: creating / managing courses (also called the educator’s vision, see Figure 5), participating in a course (apprentice’s vision) and system management (administrator’s vision). Each vision has its own peculiarities to accommodate the various functions relating to each other.

MEHRECE presents useful features to manage and structure the learning process. Moreover, implementing the SSM as a computer software required the inclusion of specific features that are inherently related to the skills space model, among which stands out the following features:
Control of automatic access by passwords;
Generation of atoms (intersection of degrees) automatic;
Different types of ratings even with uploading files;
Color code to view the current situation.

The authoring interface, shown in the left hand side of Figure 5, allows the educator to provide content information related to the course being created in compliance to its SSM (which should be defined previously). After filling up this information atoms intersections are automatically generated and the educator will have to input each of the atom’s content and its assessment, if any (see the right hand side of Figure 5).

Figure 6 shows on the left hand side, how the apprentice sees the contents of the course and at the right hand side the map that shows his/her progress on a course map. As an example, Figure 6 shows at the right hand side a two dimensional course related to the game of Chess (presented in Figure 4) where the rules are evolving on the horizontal axis and the pieces of the game are listed in the vertical axis and, at the left hand side, the atom related to the positioning of the board and preliminaries of the game (which correspond to the atom 1-1).
The apprentice’s situation position in the course is easily perceived by the color scheme used to represent each of the atoms, where:

- **Green**: acquired atoms, i.e., atoms which have been studied by the apprentice and a correct answer has been given for its assessment. This atom can be visited again in order to allow a review;
- **Red**: represent atoms which are not yet available to be visited because require their prerequisite atoms to be acquired first;
- **Yellow**: Available (freed) atoms but not yet visited;
- **Blue (border)**: Shows the current atom, that is, the last one that was visited by the apprentice. It could be an atom of green, white or orange center.
- **Orange**: An atom where that have been attempted to acquired but a wrong answer was given to the assessment. Another answer need to be tried out;
- **White**: Empty atoms, where the educator have not included any content;
- **Gray**: Shows atoms that do not belong to the SSM of that course. They are displayed because the screen has a fixed number of cells;

In order to try out MEHRECE as a framework for ECR in an e-learning environment the content of the Chess Game was used, as detailed before. It was found that technical contents seems to benefit the most from the kind of content structuring that SSM provides but rather, many other disciplines where the educator sees the possibility of inter-relate the internal modules or concepts are good candidates to be represented in a SSM and therefore, benefit from MEHRECE. The SSM for Chess and for Algorithms Construction, with all atoms and their explanatory contents and degrees in Portuguese can be accessed on [http://www2.joinville.udesc.br/~larva/mehrece](http://www2.joinville.udesc.br/~larva/mehrece).

4. Conclusions

There are different types of contents but specifically the technical content have the characteristic of enabling the apprentice an orthogonal exploration, that is, knowledge of one dimension of skills contributes or are even prerequisite for better understanding the a following. Technical Content depicts interdependent skills which would end up in a highly complex representation if a conventional hierarchical structured model is to be used. The Skills Space Model, on the other hand, seems to comply comfortably to this multitude of alternatives.

This paper presented the implementation of the Skills Space Model as a computer software and through this experience it was possible to better understand the applicability of the SSM, in particular the concept of orthogonal skills and prerequisites. SSM is a fairly new way to structure educational content and does it in a very different manner if compared to existing model. However it had not yet been implemented as a software and therefore its features as an e-learning environment had not been put to the test up to the implementation of MEHRECE.

One of the main advantages of SSM is to allow the apprentices to choose which path they want to progress in the course without missing the goal that the educator
had put up for them. Representing this possibility in a color map is very attractive, however the 2D web environment restricts how the apprentice sees as the whole map of the content (which in many cases can be 3D, 4D and so on). This is a feature of the web realization that needs to be taken into further research.

The Skills Space Model is a novelty scheme for educational content representation, an outline to view and explore such content as well as a different methodology from existing approaches that however required more research on its applicability and effectiveness.

References

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