PROCCESS OF DEFINITION OF LEARNERS STEREOTYPES TO INTELLIGENT TUTOR SYSTEM BASED ON STRUCTURAL COMMUNICATION EXERCISES

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Keywords: Learners Stereotypes, Structural Communication, Intelligent Tutor System.

Abstract: The subject of this paper is the forgotten instructional technique called Structural Communication and how learners stereotypes could be defined to a generic Intelligent Tutor System based on Structural Communication Exercise. This instructional technique stemmed from teacher's practice of analysing a learner's problem solution to an ill-structured problem. The solution described in this paper is based on some ideas of convergent and divergent cognitive learner styles. These cognitive learner styles were used to define a set of twelve basic learner stereotypes. These ideas of learners stereotypes stemmed from the observation of how learners could employ some domain's concepts or ideas in a convergence and divergence way to solve a set of ill-structured problems. This set of learner's stereotypes is represented by three independent dimensions or layers and define a Learner Model of a generic ITS based on Structural Exercise.

1 INTRODUCTION

Hannafin et al. (1999) and Jonassen (2004), among other researchers, emphasized the lack, necessity and importance of models or instructional techniques that could help the Intelligent Tutor System - ITS developer to represents some instructional activities based on ill-structured problems.

To attain this desirable representation, the ITS developer faces two basic requirements: the specification of ITS architecture and the selection of instrucional techniques. This type of challenge motivates some researches such as those performed by Arruarte et al, (2003) as well as Heffernan and Koedinger, (2002) to join instructional techniques to ITS or Authoring Tools.

In a typical ITS Architecture, the Learner Model has an important role (Murray, 2003). This Learner Model could represent several facets and information about learners. In this context, the ITS developer could typically define a set of learners's stereotypes. For example, Milik et al, (2008) used two learner's stereotypes based on spatial ability into ERM-Tutor. Other example, Parvez and Blank (2008) defines a set of learner stereotypes based on Felder-Silverman learning style model (Felder and Silverman; 1988).

This basic and important ITS requirement was also researched by Bahar (1999). Bahar identified some convergence and divergence features in learners solving ill-structured problems using Structural Communication – SC (Egan, 1976). SC is na instructional technique stemmed from the teacher's practice of analysing a learner's problem solution to a set of ill-structured problems. The result of this analytical process helps the teacher select a correct feedback message.

Despite of this, the current state of art of SC doesn't report any development of ITS based on this technique neither how learner stereotypes could be represented in a computer environment.

This paper describes how Bahar's convergent and divergent cognitive learner styles could be used to define some learner stereotypes to a Learner Model of a generic ITS based on Structural Communication exercises.

Vida Noronha R. and Torres Fernandes C. (2009).
PROCCESS OF DEFINITION OF LEARNERS STEREOTYPES TO INTELLIGENT TUTOR SYSTEM BASED ON STRUCTURAL COMMUNICATION EXERCISES.
In *Proceedings of the First International Conference on Computer Supported Education*, pages 272-277
DOI: 10.5220/0001978502720277

This paper contains 5 sections. Structural Communication is summarized in Section 2. Section 3 presents and describes a Learner Model to an ITS based on Structural Communication execises. Section 4 analyses the model. Finally, Section 5 presents the conclusion and future works.

2 WHAT IS STRUCTURAL COMMUNICATION?

Structural Communication is an instructional technique that individualizes learning, provides controls for the process by which the learner moves through the lessons, faces him with challenges to construct his own multifaceted responses to complex open-ended problems and ill-structured problems, analyses these responses and firmly provides complex, multifaceted, feedback on all relevant issues revealed by his answer (Egan, 1976).

The Structural Communication technique involves the development of special units of domain study. Each learning unit should be structured in such a way that the learner spends approximately an hour of study to complete the activities foreseen by the author. However, the work of the learner is somewhat analogous to the research of the content and planning of the structure of an essay or term-paper type of response - a task that typically takes many (sometimes many dozens) hours. Thus, the learner has the opportunity to engage in a much larger number of creative knowledge-construction exercises during the time available for study on a given course. A SC learning unit usually contains the following sections:

- **Intention** - This section defines what should be learned and to what level or intensity. It supplies a general vision of the objectives and context for the unit of study.
- **Presentation** - This section supplies descriptive information on the subject, possibly practical exercises or case studies. It can be composed of text materials, videos, simulations, computer-based training systems, hypermedia courses, adaptive hypermedia systems, electronic games, and site visits, among other forms.
- **Investigation** - This section presents a group of usually 3 or 4 interrelated, challenging and generally open-ended questions on the subject of the Presentation. They constitute the challenge for the learner who responds by selecting elements from the Response Matrix presented next.
- **Response Matrix** - It is a response-generating instrument formed by a large number of elements, typically 20, from the domain under study; they can be sentences that summarize an idea, key words, concepts or principles contained in the Presentation. The learner constructs a response by selecting those elements that are considered part of a complete response to the complex question that is being addressed.
- **Discussion** - This section is composed of two parts: a group of " if - then - else " rules and a series of feedback comments elaborated by the author, each one associated with one of the rules. The comments have a constructive purpose and they discuss in depth the reasoning used by the learner when selecting or omitting certain items or subsets of items from the Response Matrix. They seldom classify a response as incorrect and never supply a "correct" response, but rather encourage the learner to think again and to think deeper and wider around the issues being addressed.
- **Points of View** - This last section is used by a SC exercise's author to present other interpretations or conflicting points of view and to revise some aspects presented earlier. This section finishes the interaction between the learner and author, which mimics a virtual dialogue between them.

One may ask why the potential of researched methodologies such as Structural Communication has not been realized by ITS's developers. One possible reason for this lack of computer applications of a theoretically "good idea" is the gap of Models to represent an SC Unit and SC Domain Knowledge in a computer environment.

3 LEARNER MODEL TO STRUCTURAL COMMUNICATION EXERCISE

The learner stereotypes are defined in this work using three layers and they are based on the learner's last solution to a problem and recorded solution history. The last learner solution is analysed in the first layer and clustered based on domain concept convergence. This solution can be classified in Convergent (C) or Divergent (D). The Second Layer analyses the history of solutions and classifies the learner in Convergent (C), Mixed (M) or Divergent

(D). Finally, the Third Layer analyses the history of solutions and looks for a hidden convergence in all recorded solutions. The learner is classified as having presented a Convergent Concept Path (C) or a Divergent Concept Path (D) if this third layer finds some convergence in all solutions recorded in the learner's solution history.

In this context, an example of a hypothetical learner "A" is represented in a three dimensional space in Figure 1. This space can represent any learner stereotype or learner behaviour. Learner "A" has a **C**onvergent Solution, a **M**ixed History of Solutions and a **D**ivergent Concept Path.

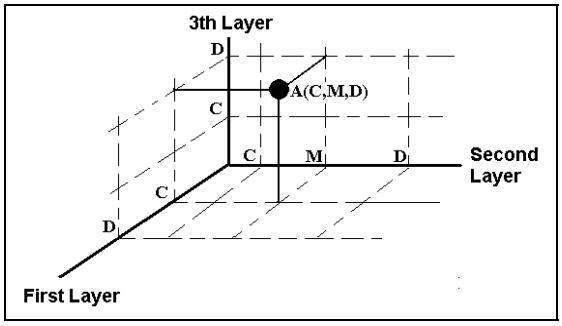

Figure 1: Representation of Learner Stereotypes in Three Dimension Space.

This current paper section is composed of 4 subsections. Section 3.1 describes how Response Matrix Elements selected by a learner could be represented in a symbolic expression to be used by a computer system. This expression records the presence and absence of some domain concepts in the Selected Response Matrix Element. Sections 3.2, 3.3 and 3.4 describe a computer algorithm to analyse this expression. The result of this analisys is a more precise and refined learner classification.

In this example, a symbolic Response Matrix with 20 elements is considered. These Response Matrix Elements are sequential abstract elements labeled as { F_1, F_2, F_3, ... , F_{18}, F_{19}, F_{20} }.

The same example also considered that Concept Graphs could be associated with all Response Matrix elements F_n. These Concept Graphs are very similar to Novak's Conceptual Maps. (Novak, 1998). Figure 2 illustrates this idea. In this figure, the following Response Matrix Elements {F_1 , F_2 , F_{11} , F_{12}, F_{13} and F_{18} } were associated with some important concepts or ideas detached from domain by the SC exercise author (Noronha, 2005). These concepts or ideas are labeled as Knowledge Keyword - KWK in this context (Noronha, 2005).

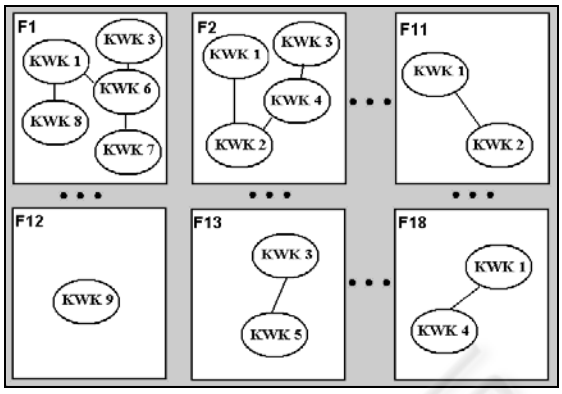

Figure 2: Graph Representation of some Response Matrix Elements.

How can these important concepts or ideas be represented in a symbolic expression? The next sections define expression of concepts and show how learners can be classified in three layer-based learner stereotype model.

3.1 Expression of Concepts - S_F

The Expression of Concepts - S_F represents the presence of each KWK in each Response Matrix element selected by a learner to compose a solution. The index "1" is used to indicate the presence of each KWK inside the Matrix Response elements.

For example, the following expressions S_{F1} and S_{F2} represent the elements F_1 and F_2, in Figure 2. The set composed by elements KWK1, KWK3, KWK6, KWK7 and KWK8 corresponds to element F_1 and another set composed by KWK1, KWK2, KWK3 and KWK4 corresponds to element F_2.

S_{F1} = 1.KWK1 + 1.KWK3 + 1.KWK6 + 1.KWK7 + 1.KWK8

S_{F2} = 1.KWK1 + 1.KWK2 + 1.KWK3 + 1.KWK4

All Matrix Response elements can be represented by a similar expression to those described in this example.

3.2 First Layer: Classification of Learners Based on Individual Analysis of Learners Solution

In this first layer, the problem solution dispatched by learner must be analysed in an isolated way. Any solution by the learner could be composed by some or all Response Matriz elements *Fn.* For example, a learner could select the following Response Matrix elements { F_{11}, F_{18}} to compose his/her solution to

a challenge or problem defined in SC Intention Section. These elements are illustrated in Figure 2. Another learner could select other Response Matrix elements such as { F_{11}, F_{13}}.

This example is illustrated in the following Figures: 4 a) e b). The solutions are labeled *Sa* and *Sb*, in these figures. The elements F_{11} and F_{18} compose the solution *Sa*, whereas the elements F_{11} and F_{13} compose the solution *Sb*.

Figure 3a) illustrates a solution composed of Response Matrix elements F_{11} and F_{18} represented as Venn diagramas. These matrix elements share the element KWK1. This is represented in Figure 3a) by means of an overlapping region. In this case, the solution is classified as Convergent to KWK1.

In contrast, Figure 3b) doesn't show an overlapping region. In this sample case, the solution is classified as Divergent to KWK1, KWK2, KWK3 and KWK5.

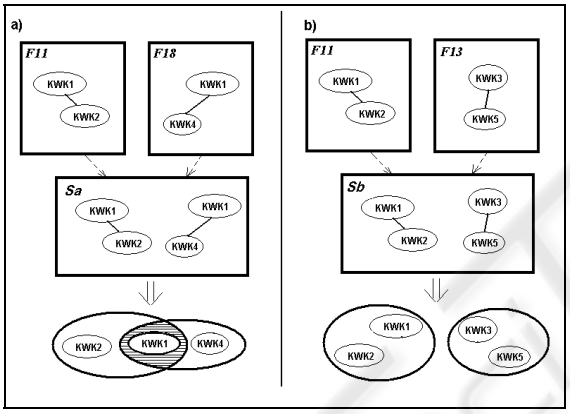

Figure 3: Example of Problem's Solution Analysis.

These analyses could also be conducted using the Expression of Concepts described in section 3.1. Each solution expression is created by separately adding the corresponding index for each KWK. For example, the solution illustrated in Figure 3a) can be represented by the following expression of concepts:

$$S_{F11} = 1.KWK1 + 1.KWK2$$

$$S_{F18} = 1.KWK1 + 1.KWK4$$

$$S_a = S_{F18} \wedge S_{F11} = 2.KWK1 + 1.KWK2 + 1.KWK4$$

The KWK1 has a "2" index because it appears two times, in F_{11} and in F_{18}. The index analysis of the concept expression identifies which KWKs have superior index values. These KWKs indicate a convergence of ideas or concepts. KWK1 has a superior index value, in this case. Because of this, the solution is classified as Convergent because it converges to KWK1.

The expression of concepts to solution illustrated in Figure 3b) is represented by :

$$S_b = S_{F_{11}} \wedge S_{F_{13}}$$

$$S_b = 1.KWK1 + 1.KWK2 + 1.KWK3 + 1.KWK5$$

The index analysis of expression S_b does not identify index values above "1". This means that the solution is not converging on any idea or concept previously defined by the author. So, this solution is classified as Divergent to KWK1, KWK2, KWK3 and KWK5.

To summarize, if the concept expression of solutions had an index value higher than "1", this solution is classified as Convergent to KWKs with a superior index value. If the concept expression did not have an index higher than "1", this solution is classified as Divergent to KWKs with a "1" index.

3.3 Second Layer: Classification of Learners Based on History of Problem Solutions

This layer classifies the learner as Convergent, Divergent and Mixed History of Solutions. If all solutions recorded in learner's solutions history were classed as Convergent, then he/she is clustered as Learner with Convergent History (C). If all solutions recorded in learner's solutions history were classed as Divergent, then he/she is clustered as Learner with Divergent History (D). If the learner's solutions history has solutions classed both Convergent as Divergent, then he/she is clustered as Learner with Mixed History (M).

Although this basic learner classification uses only three clusters, these clusters can be detailed by the SC author. For example, a learner clustered as a Learner with Mixed History could be divided into smaller categories namely:

- More Convergent, when the amount of Convergent solutions has higher value than the amount of Divergent solutions.
- More Divergent, when the amount of Divergent solutions has higher value than the amount of Convergent solutions.
- Homogeneity, when the amount of Divergent solutions is exactly the same as those of classed as Convergent.

3.4 Third Layer: Classification of Learners Based on Problem Solution History Path

In this Third Layer, the learner model looks for some hidden convergence in learner's solutions history. For instance, if one learner is classified in Second Layer as Learner with Mixed History, and he sequentially presented the following solutions exemplified in Table 1, is it possible for the Learner Model to automatically identify some hidden convergent ideas?

Table 1: Example of Learner with Mixed History record.

S	Solution classification	Expression of Concepts
S0	Convergent to KWK1	$S_0 = 2.KWK1 + 1.KWK2 + 1.\mathbf{KWK4}$
S1	Divergent	$S_1 = 1.KWK1 + 1.KWK3 + 1.\mathbf{KWK4} + 1.KWK5$
S2	Convergent to KWK2	$S_2 = 2.KWK2 + 1.\mathbf{KWK4} + 1.KWK8$
S3	Divergent	$S_3 = 1.KWK1 + 1.KWK3 + 1.\mathbf{KWK4}$

The analysis of the set of solutions presented by learner exemplified in Table 1 indicates one hidden convergence. ***KWK4*** is present in all learner's solutions. In this symbolic example, even though no solution had been classified as Convergent to KWK4, this hypothetical learner used the KWK4 element in most or all solutions. This learner is classed in third layer as a Convergent Concept Path.

To summarize, the analysis of the history of the learner's solutions represented in Table 1 gives the following information:

- The learner's clustering in the First Layer used the last solution, S_3 . This solution is classed as Divergent.
- The Second Layer clustered this hypothetical learner as a Learner with Mixed History. This hypothetical learner oscilated among all types of solutions. Sometimes he/she presents Convergent Solutions, sometimes he/she presents Divergent Solutions.
- Finally, the Third Layer identified a hidden convergence. This hypothetical learner used the ***KWK4*** in all solutions presented. This KWK during the entire solution process may indicate a possible learner belief.

4 CLASSIFICATION ANALYSIS

The independence of classification i) of individual solution, ii) from history solution and iii) from Concept Solution Path allows the specification of layers that can be used to cluster learners based on a set of stereotypes including the three layers. These stereotypes were also defined based on the way the analytical process can be conducted. The ways are summarized as follows:

- **Individual Solution** – The learners can be classed as Convergent or Divergent. This type of classification is called "Individual Solution".
- **Individual Solution History** – The learners can be classed as Learner with Convergent History Solutions, Learner with Divergent History Solutions or Learner with Mixed History Solutions. This type of classification is called "History Solution".
- **Collective Solution History** – The learners can be classed based on Convergent and Divergent ongoing ideas inside the learner solution history. This type of classification is called "Solution Concept Path".

The combination of these three layers defined in this paper, allows the identification of 12 basic learner stereotypes that can be found in an SC exercise. These stereotypes are presented in Table 2.

Table 2: Basic Stereotypes of Learner Model's.

Layer of Classification			Learner's Cluster
First	Second	Third	
Divergent	Divergent	Divergent	**DDD**
Divergent	Divergent	Convergent	**DDC**
Divergent	Convergent	Divergent	**DCD**
Divergent	Convergent	Convergent	**DCC**
Divergent	Mixed	Divergent	**DMD**
Divergent	Mixed	Convergent	**DMC**
Convergent	Divergent	Divergent	**CDD**
Convergent	Divergent	Convergent	**CDC**
Convergent	Convergent	Divergent	**CCD**
Convergent	Convergent	Convergent	**CCC**
Convergent	Mixed	Divergent	**CMD**
Convergent	Mixed	Convergent	**CMC**

Why these stereotypes showed in Table 2 is important? Because, the learner stereotypes can be used as guide to formation of feedback message (Noronha, 2007; Parves and Blank, 2008).

If an ITS running a SC exercise has only one stereotype then all learners must match with this stereotype. On the other hand, if there is a high quantity of stereotypes, then there is more clusters in this ITS that the each learner could be suitable

match.

This ability was not defined by creators of SC, despite it was described by Egan (1976). The feedback messages could be also adapted based on learner's model. For example, a feedback message could be composed by some "real samples", "study of cases", tables or charts. This message could be presented to learner clustered as CMC and CCC. A similar message could be formed by definitions, explanations and desmonstrations of some domain concepts. This message could be presented to learner clustered as DDD or DMD. Clearing some fuzzy aspects of domain is the purpose of both feedback messages previously exemplified, but the messages use distinct ways to accomplish it. The learner's stereotypes were used to envelop the feedback message.

5 CONCLUSIONS

This paper described a model of learner's stereotypes definition based on three independent layers.

These layers were defined based on convergence and divergence characteristics of learners. These ideas of learners stereotypes were derived from the observation of how learners could employ some domain's concepts or ideas in a convergence and divergence way to solve a ill-structured problem. These main ideas or domain's concepts are named KWK and typically they are defined by the author of SC exercise.

This paper expand some SC characteristics adding the possibility of employ a Learner Model during the excecution of SC exercise. In this new context, feedback message can also be selected and defined based on learner stereotypes.

The contributions of this paper are the definition of learner stereotype and a generic learner model that can be used in Intelligent Tutor Systems based on SC Exercise. Future work includes some research questions such as how to define models of feedback messages based on each of the 12 stereotypes described in this paper.

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