# A Suite of Authoring Tools for the Design of Structural Communication Activities in Web-Based Environments.

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#### Abstract.

This paper presents the rationale for and the architecture of an intelligent authoring environment and tool set that supports the work of teachers-authors who wish to develop instruction using the pedagogical technique called Structural Communication. Structural Communication (SC) is a pedagogical technique that can provide an objective snapshot of a participant's sophisticated intellectual skills and cognitive structures. The SC can be used to develop Problem Based Learning Instruction in a ITS paradigm. The computer environment uses techniques of Automatic Text Summarization to help teachers in the authoring process and Clusters Algorithms to help to identify the main strategies and help to author the appropriate feedback. The environment permits the authors of SC exercises to share their expertise with other teachers and domain experts, thus acting as a collaborative design and learning environment for the teachers.

#### 1. Introduction

The current interest and increased activity in distance education is largely driven by increased availability and decreasing costs of the new information and communication technology infrastructures that makes it possible to offer E-Learning on both a national and international scale. One relevant issue in this context is faculty workload. An extensive and detailed account of two years of E-learning in a university context shows that whilst learners work just a little more time in online versions of a course as compared to the conventional face to-face versions of the same course, the teacher workload is reported to be more than double across whole semesters and programs. This raises the question of whether online learning, as a regular and mainstream course delivery alternative, is in fact sustainable over the longer term.

One way to minimize this problem is to employ an instructional technique which can at the same time diminish the teaching workload and maintain high quality online courseware. Although it is not a panacea, there exists an instructional technique, named Structural Communication (SC), which can help to solve this requirement through self-instruction activities. SC was initially proposed in the UK in the 1960's as an alternative to the thenpopular programmed instruction methodologies. It was designed for subject matter and learning situations that demanded critical analysis and discussion of alternatives as opposed to giving correct responses to predetermined, well-structured problems (Egan, 1976). But, despite some well-succeeded initial development, the use of this technique practically vanished. The problem was the difficulty to manually develop a structural communication activity and some attempts to automate the whole process over the years have failed.

However, recent advancements in the development of intelligent tutoring systems, adaptive hypermedia systems, information retrieval, and linguistics software have changed the scenario [Murray, 1999]. [Romiszowski, 2000] has applied structural communication to the online study and discussion of case material by co-operative Web groups. [Noronha et al. 2004] have presented an intelligent prototype system for presenting structural communication activities. But, to the knowledge of the authors, there is no knowledge-based authoring tool and environment for the preparation of structural communication activities. The goal of this paper is to present the structure of a proposal for such a partially implemented environment.

The paper is organized as follows. Section 2 shows a brief overview of the key aspects of SC and the issues involved in developing SC units. Section 3 discusses some possible approaches to machine support for the design and development of SC units. Section 4 presents the architecture of the proposed authoring tool. Finally, Section 5 presents the conclusions.

### 2. Structural Communication

In contrast to other instructional techniques, Structural Communication doesn't value the simple reproduction of acquired knowledge on the part of the learner, but rather seeks to develop a deep understanding of the structure as well as the content of a complex knowledge domain. It is a form of self-instruction exercise or unit, which is based on the concept of shared human-machine intelligence in the presentation and conduct of learning activities in complex subject matter domains and with objectives that are more process-related (e.g. critical thinking skills application and development) than product-related (e.g. the mastery of specific content).

The structure of SC is presented in Sub-section 2.1 and Sub-section 2.2 describes the general process of designing and developing SC learning units, and identifies some areas of possible difficulty.

### 2.1 Structure of SC

The Structural Communication methodology involves the development of special units of study of the domain. 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) of 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. This benefit is additional to some of the other pedagogical benefits identified in the research on SC. 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 CBTs, hypermedia courses, adaptive hypermedia systems, intelligent tutoring 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 (Figure 1). They constitute the challenge for the learner, who responds by selecting elements from the Response Matrix, presented next.
- Response Matrix This is a response-generating instrument formed of a large number of elements, typically 20 to 40, from the domain under study (Figure 2). They can be sentences that summarize an idea, key words, concepts or principles contained in the Presentation.
- 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 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 to present other interpretations, or conflicting point of views and to revise some aspects presented earlier. This finishes the interaction between the learner and author, which mimics a somewhat virtual dialogue between them.

One may ask why the potential of researched methodologies such as Structural Communication has not been realized in large-scale applications in real-world educational systems. One possible reason for this lack of practical application of a theoretically "good idea" is that the design and development of SC units is seen as a complex and difficult task by most educators who have attempted it. Therefore, a logical next step is to develop intelligent authoring tools that may simplify the human author's task.

During the first half of the sixteenth century, the Merchant Adventurer's Company became one of the most poweful and influential groups in England. They controlled the lucrative cloth trade with Antwerp on which much of England's growing prosperity depended. Their relationship with the government was usually close, and they were respected and considerately treated by even the highest in the land. Their wealth and pride were such that they added considerably to the pomp and splendour of state occasions. Consider why this company nd its members should have achieved such a position of wealth and power in sixteenth-century society. Why did it all happen ?

Using the RESPONSE MATRIX, construct a picture of those factors which were favourable to the growth in power and wealth of the company.

### Figure 1 - Example of Investigation Section

1-Increasingly often interlopers ignored the Merchant Adventures monopoly and traded in cloth with the Continent	2-English seamen hoped for the good luck of the Spaniards in finding silver and gold.	3-Parliament backed up the Merchant Adventurers'claim to control the sale of cloth abroad.	4-Money was available in London, to back risky expeditions.
5-Henry VIII debased the coinage.	6-Some foreign trading organizations were weakening.	7-Trade with the continent was disrupted by wars of religion and the Spaniards'destruction of Antwerp.	8-Henri VII negotiated the "Intercursus Magnus".
9-The Merchant Adventurer's monopoly was withdrawn.	10-Some of the new trading ventures reaped enormous profits.	11-The Merchant Adventurers Introduced "stints".	12-It was "outport" merchants who first traded with the Americas.
13-In 1485 the custom tax on cloth was only 3 percent of the cloth's value.	14-The price rise affected the Continent more strongly than England at first.	15-Steps were taken to repair the damage done to the coinage by Henry VII.	16-The Merchant Adventurers had to pay heavily for the privileges granted to them in Elizabeth I's reign.
17-The formation of the joint-stock companies offered a new means of financing trading expeditions.	18-The Merchant Adventurers continually appealed to the Government for protection against competitors.	19-By trying to sell undersized cloths during the boom years, the Merchant Adventurers damage their reputation abroad.	20-The Merchant Adventurers controlled nearly all the cloth passing through the port of London.

Figure 2 - Example of Matrix Response Section.

# 2.2 Developing a SC Unit

The task of developing a lesson that applies SC to teach some complex understanding to learners is not easy work. The teacher needs to possess the capacity to foresee all the more probable answer combinations that learners are likely to supply. This requires a deep understanding of the learning problems and misconceptions that learners typically have with the domain in question, in addition to full understanding of the domain itself. The novice teacher generally doesn't have this level of expertise. The author needs to identify which topics of the subject are more important. He must elaborate intellectual challenges that cause reflection, restructuring of previously held concepts and promote interest in further discussion of the issues involved. He must identify the core issues of the domain and represent them through a set of elements that form the response matrix. Having made predictions on what response strategies learners may typically follow, the author writes open-ended, constructive, feedback messages for each of these strategies.

The first and second sections of the Structural Communication exercise (Intention and Presentation) are not all that hard work for the typical author. These sections could be created using traditional ID techniques or employ a tradicional ITS structure. The Intention is similar to the statement of Objectives in conventional instructional design and the Presentation is very like the course study materials that may be prepared for any conventional course.

The author, when creating the Investigation, Response Matrix and Discussion sections, needs to be able to not only interpret new situations in terms of principles, but also simulate and predict results as well as elaborate solutions for complex problems. This technique therefore demands creative thinking on the part of the teacher-author because it values deep and highly structured understanding of the domain in question and not just simple memorization of information or mastery of simple concepts (Egan, 1976; Romiszowski, 2000).

The teacher, when developing a unit of study with this technique needs to be able to do the following: a) Identify the main topics of the subject and how they are interrelated, b) Elaborate open-ended questions that fully explore the instructional objectives, c)Foresee the solution strategies that will be used by learners in the solution of the tasks, d) Create the dialogues that form the discussion. The purposes of these messages in the dialog depend on the learner's strategies adopted to respond to the challenges set, on the objectives of instruction and on the teacher's interpretation, or "view" of the domain.

How to find and develop these abilities in teachers is not the purpose of the present work. Although initial training plays a role, these abilities are assumed to continue to grow in the teacher during many years of practice. Lesgold (1984) emphasizes that a person acquires expertise through a repetition process (i.e. like a marathon athlete) or through exposure to a great diversity of cases, conditions of situations (i.e. like a chess player). Romiszowski (1981) draws a similar distinction, suggesting that the first type of procedure is more appropriate for the acquisition of repetitive or "reproductive" skills, while the second is better for mastering the more creative or "productive" skills. However, there is an overall "best practices" process that has been found to lead most often to satisfactory designs. Such best practices should be promoted and supported by the proposed online tools for the design of SC units.

### 3. Machine Support of the SC Design and Development Process

There is not that much available in the way of technology-based support tools for the SC design procedures described above. But there are some existing tools that may be applied to some parts of the authoring process. The literature recommends the employment of Concept Maps to identify the main topics of the subject domain and their interrelationships (Novak, 1998). Existing work carried out over the years by many researchers has contributed both tools and research on their use for purposes similar to the initial analysis stages of the SC design process.

Some particularly relevant work is the research agenda being implemented by the Institute for Human and Machine Cognition (IHMC) at the University of West Florida. The Institute has also developed a suite of automated concept mapping tools (IHMC Cmap tools) that may be downloaded from the Institute's website. This suite has been successfully applied by the IHMC itself and by other researchers to supporting educators and subject specialists in the analysis and organization of complex subject matter content for the purposes of course design.

These kinds of tools may therefore be employed for supporting the initial stages of the SC exercise design process. They may also be helpful in mapping out the pattern of typical misconceptions and difficulties that learners encounter in the domain, through the comparison of expert-generated and novice-generated concept maps.

Another potential computer technique that may be used to identify the main topics of the subject is Automatic Text Summarization - ATS. This is a process that identifies and locates the most important information in a given source material and produces a condensed summary of that source designed for a given user group or task. The technique produces or selects a piece of text in a group of documents. This selection is based in some rules defined by the user. The method can use statistical procedures and/or heuristic functions to refine the process.

We now come to the unique, and possibly most difficult for the novice teacher, stage of the design process - how to identify which response strategies learners will follow and how to elaborate the feedback messages that will be associated with each pedagogically significant strategy. Romiszowski (2004) recommends some procedures to the author of SC exercises that focus on the implementation of a case study methodology. These procedures are: i) Define the "problem", ii) Analyze the problem and assemble the data and select or create a case or situation to be commented or resolved by the learner, iii) Design the case situation, iv) Develop the case material, v) Evaluate the case material and vi) Develop the SC lesson plan. These recommendations may be quite useful to the teacher-author, but they are not easy to implement. It is from this point on in the SC learning unit design process that we see the value on an Intelligent Authoring Tool Environment.

How to identify learner's probable response strategies and to write appropriate feedback messages for each relevant strategy is a problem for the novice teacher because he doesn't have enough experience to identify them and interpret the learners' reasons for selecting them. Two techniques may be used to identify the learners' response strategies and to link them to the appropriate feedback messages, previously written by the author of the SC, which are to be shown to the learner. The first of these is a rule based system or expert system. A Rule-Based System stores the rules in an "if ... then ... else ..." structure. This technique was used in the past to elaborate medical diagnosis and other expert advisory systems (Reiser et al. 1992; Lesgold et al. 1992).

The second technique is Cluster Algorithms, which are based on the idea of similarity or proximity. In contrast to expert systems that utilize a set of rules to find a "match" with specific entry data points, the clusters algorithm method places a given entry data point in a class together with similar, though not identical, points. The cluster algorithm therefore creates groups of similar instances. In the SC case, the groups would be composed of learners with similar response strategies. We believe that teachers and domain experts could be the source of samples for this second technique. The samples would represent how the teacher or expert in the domain resolved the challenge. The Cluster Algorithm will classify the learner's answer in relation to the groups thus formed by the author.

### 4. Architecture of the Proposed Authoring Tool.

This section presents a computer architecture that can be used to support the authoring process of a SC unit of study. This computer environment also makes it possible for experienced authors to share their expertise (knowledge acquired in years of practice) with novice teachers or authors. Further information on this learning shell and environment are available elsewhere (Noronha et al., 2004).

The authoring process is divided in two modules. The first one, shown in Figure 3, gets information about the subject domain and the instructional objectives. The second tool, shown in Figure 4, makes it possible for the author to create a "learning path" (which corresponds to the Intention and Presentation sections), develop the Response Matrix, define the response strategies and store them as a set of rules, and indicate which instructional messages will be shown to the learner in each case.



Figure 3 - Pre-Authoring Module.



Figure 4 - Authoring Module.

# 4.1 The Pre-Authoring Tool

The Pre-Authoring Tool's main purpose is to obtain general information on the subject matter, the learner's information and the instructional objectives. The Authoring Tool will need this information to produce the Structural Communication lessons.

The pre-authoring task illustrated in Figure 3 is composed of the following:

- 1. **Definition of the Presentation and Intention Section**, This tool makes it possible to author and store in a Knowledge Base the instructional main documents and domain knowledge key words. The author also defines the Learning Path. The Learning Path is the sequence of Internet files that will be shown to the learner. The HTTP addresses and the respective instructional objectives are stored in a Knowledge Base. These pages will be shown to the learners during the initial training section.
- 2. **Definition of Student Model**, A student model is a key part of many Intelligent Tutor Systems. This model is constrained to a pairs of "attribute-value". This attribute-value pair will store a small part of the instructional goal the learner needs to attain. A group of such learner model components makes up a meta-model. This meta-model will be used to register the learner interactions in the training section.
- 3. **Definition of the Instructional Goal**. Instructional Objectives are composed of a collection of sub-domains and their corresponding level of learning (i.e., essential,

desirable, important and not important). The course content is specified by the author and classified according to the minimum level of learning required for each objective of the course. The CONTENT - LEARNING-LEVEL pair allows the relevant algorithm to identify and order the sentences in accordance with their relative priorities. For example, a sentence that contains only words that were classified as unimportant will be ordered in a position below sentences that contain some words that were classified as essential. This collection of words has a similar function as a Thesaurus in the work of Srinivasdan (1992) and Baeza-Yates (1992). Also, the instructional key words must be associate to the instructional goals.

4. Extract Sentences and Keywords, This module is responsible for selecting and sorting the sentences in Internet documents whose http addresses where stored in the Knowledge Base "Candidates for Response Matrix Elements". The algorithm that does this is very similar to the one proposed by Luhn (1958), but with some small differences. These differences include a search using the Instructional Goal (key words associated) and the Learner Model as search parameters, on the basis of statistical calculus. The sentences selected by this algorithm will be candidates for inclusion as Response Matrix elements. These elements are part of the text in the Presentation section. This resource makes possible for the author to avoid the inclusion of elements that are not in the Presentation section. These elements will be used in constructing the Structural Communication lesson

# **4.2 The Authoring Tool**

The authoring task is shown in Figure 4. It is composed of the following:

- 1. **Interface for selection and editing of the Response Matrix Elements**. This interface allows the author to indicate which elements stored in KB will be included in the Response Matrix. These elements were extracted from the Presentation section (typically a group of Internet documents). The author can edit these elements or create others and insert them in the "Candidates for Response Matrix Elements" database.
- 2. **Interface for Editing the Challenge Questions.** The author can edit the challenge questions that will lead the learner to achieve the instructional objectives. Authoring these open-ended questions demands a deep knowledge of the subject on the part of the author.
- 3. Interface for sharing, selection and editing of the response strategies. The response strategies are groups of elements selected by a learner from the response matrix to respond to a given challenge question Each response strategy will typically include, or omit, certain elements from the matrix that the author considers to be key elements for his evaluation of the response. These key elements form a set of "if ... then ... else ..." rules for the selection of appropriate feedback messages for each response strategy (i.e. if included elements number {1, 5,17} or omitted elements number {4, 6, 7} then read comment A). This rule represents the author's "feedback strategy" for responding to a specific set of possible response strategies to a given challenge question. The author edits the feedback comments, which will be shown to learners that reply in particular ways. Also, other domain experts may be invited to register their own set of feedback comments and strategies.

The author can access these other feedback strategies to specific learner responses to the problem to see to what extent he agrees or disagrees with other domain experts and, possibly, to extend or modify his own strategies and comments. This final set of strategies composes the knowledge base in the Expert System, developed into a learner's learning shell. The authoring process interface is similar to the learning shell. The author just selects the required elements by means of checkboxes and then writes the feedback messages. The rules that define the feedback strategies and the respective feedback messages are stored in a knowledge-base.

The author need not identify all possible learner strategies. He will indicate which strategies, in his opinion, are more important to the current challenge question. When a second author or domain expert edits this lesson, he will indicate his (possibly other) set of feedback strategies for responding to specific learner response strategies to the problem. The diversity of possible strategies for solution of a challenging problem is the main core of Structural Communication. It may be hard for one author to identify all of the learner response strategies worth commenting, but a group of authors composed of both novice and experienced and competent teachers, together with other domain experts, could together quickly generate all the principal feedback strategies that may be required to close the gap in any learner's knowledge or interpretation of the domain being studied.

#### 5. Summary, Limitations and Future Work

This paper presented the architecture of an authoring tool to help authors produce Structural Communication Lessons. This authoring tool makes it possible for the author to record his viewpoints about a given subject domain and his strategies for solution of complex problems in the domain. This record is allied with a deeper discussion of the subject. The author's strategies and author's points of view are shared with other authors. The environment emphasizes the acquisition of deep and structured knowledge of the domain instead of the simple repetition of a few specific concepts and facts.

The author has some resources to assist him during the authoring task: i) a simple algorithm to identify the main sentences, based on the Automatic Text Summarization technique (Luhn, 1958); ii) a www-interface to collect information; iii) some automatic mechanisms to represent the author's feedback strategies and selection rules that will be loaded by the learning shell (Noronha et al. 2004).

This authoring environment makes it possible for the author to employ any pedagogical technique in the Presentation and Intention sections. The Structural Communication main core (Response Matrix, Challenge Questions and Discussion guide and rules) is used to outline the instruction.

Until now, the environment just uses the logical connectives AND, NOT and OR to produce, store, load and interpret the rules defining the feedback strategies. Connectives such as TwoOrMore, AtLeast(# N elements ), NoMoreThan(#N elements) for example, are still being developed.

Future work will employ this environment to allow authors to develop problem based learning exercises. SC will be used within ill-structured problem domains to test out some of the current theoretical views on problem solving in ill structured domains we hope to validate Structural Communication as a technique to help teachers and authors to create effective learning structures within ill-structured problem solving domains. Can Response Matrix -RM reduce the lost of student's goal when he creates a soluction to il-structured problem ? Can Response Matrix and Discussion Guide meassure the apprentice's misconceptions and gaps of konwledge ? Can SC be used to define the student's model in a ITS environment ? Those questions will lead future researches.

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