Chapter 3

A CONSTRUCTIVIST LEARNING STUDIO BASED ON COGNITIVE TIME ANALYSIS

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1 INTRODUCTION

The role AI plays in educational software design and construction is in constant evolution as underlying educational frameworks and paradigms change. Frequent criticisms have arisen with respect to the tutoring-focused, goal-based, knowledge domain transfer, of course material. It has been realized that the modelization of the learning process outweighs the characterization of domain knowledge (Akhras & Self, 1998; Espinosa & Ramos, 1998; Espinosa & Ramos 1999). However, purely instructivist [human, and recently machine] tutors, relying on knowledge transmission, are still mainstream in classrooms around the world (Latchman, Salzman & Gillet, 1999). Therefore, domain models and task models are being *complemented* with cognitive state models (Andriessen & Sandberg, 1999) and expert machines to handle these (Murray, 1999). According to these lines of thought, however, human cognition is only considered as part of ontology when it comes to learning environments where collaboration enters the scene. We maintain that fulfilling pedagogic goals in an Instructivist courseware always motivate the human being to make use of an autonomous cognitive history and data, both of which are *interpreted* in particular ways depending on a person's *singularity* (Espinosa & Ramos, 1996c). However, such behavior cannot be specified as a consistent model, nor is fully formalizable, given its non-predictive, non-monotonic, non-precise, and holistic, nature. Furthermore, sometimes it is not even perceivable, or evident, to the instructor, the student, or the computer software. The reason: in most cases, the core of the instructional design relies on the fact that learning proceeds by tacking, and solving, problems, *correctly*. Pedagogic planning for structured success is an easy solution to formalizing procedural domains (Andriessen & Sandberg, 1999). However, *people learn from their mistakes* (Cox, 1996), which is a far more complex, and non-structured, scenario, because it is a *holistic* one. Reasoning from failure is a cognitive task digging into the very nature of human introspective capability. Non-cartesian qualification of human comprehension is nowadays considered to be a direct result of analysis of the *spoken language*, as well as its decoding, a good reason for attempting to understand how do we understand something. The currently mainstream research strand on tutorial dialogues is based on this fact. Ignoring such cognitive state transformation during single-student performance in front of a computer loaded with educational, hereby called *Learning Studio*, software, is equal to assuming that a default (i.e. ideal) behavior is fully characterizable when performing task modeling on a single person. In our perspective, this does not hold. In contrast, we work in the intersection of behaviorism and cognitive science, and show that monitoring of single-actor activities suffices to *evidence the total/partial existence, or incomplete/flawed occurrence of*, a singularly-generated cognitive learning process evidencing learning. We explain the basis for such an argument in sections 2 and 3.

Our work in Instructivist-applied Constructivist educational software has evolved from the definition of an agent-oriented approach to designing observable and vaguely-interpretable, but non-Constructivist Instructional Graphs called *Educational Measurement Instrument* (EMI) (Espinosa, & Ramos, 1996a; Espinosa, Boumedine & Chirino, 1996b), to the formalization of cognitive phenomena in non-monotonic, and temporal logic terms (Espinosa & Ramos, 1997). The EMI Model monitored instructivist (i.e. behaviorist) interactive course designs that uncovered real patterns of conduct during classroom activities and enabled us to watch for screens and lessons that were incorrectly, partially, or seldom, used, from the Objectivist standpoint. This provided data to help computer tutors compare this conduct to ideal ones. The next step has been to incorporate cognitive capabilities to EMI, thus addressing Constructivism. Cognitive data evidencing unpredictable (i.e. "incorrect") behavior is far harder to discover than ideal behavior, so ontological thinking is required to characterize it, without trying to "mimic" the complete process inside the computer. One reason for this difficulty is that although instructional design, the dominant technique for educative technology, is deeply rooted in behaviorism, ironically tends to hide student learning behavior detail, making it hard to detect key actions which could have led to failure in learning, inherently helping professors guide their students to a better educational situation. We attempt to clarify this phenomenon in section 3. Our assumption is that AI plays a key role in providing for better mechanisms to uncover subtle events in students' conduct, but not to reproduce them in formal terms. In this case, a software agent approach to Temporal Modal Logic engines (to be explained in section 4) served as a vehicle to data-mine an educational studio, or active learning environment, through Cognitive State Modeling. The learning process is thus addressed, although many issues on Instructional Design are still unresolved.

This agent-prone evolution has been clearly consistent with the mainstream in computer-assisted education, as reported in (Andriessen & Sandberg, 1999), in the sense that "intelligent" behavior of a software agent, or similar expert system, has not been proven a conclusive gadget for effective learning outside experimental situations (Derry & Lajoie, 1993). Throughout the process, we have deepened our research into finding ways of discovering, and recording, of the precise moments in time, and their related circumstances, in which the cognitive events leading to a particular student's learning, or knowledge discovery, strategy (i.e. the *Cognitive Equilibration, Contradiction and Structure Construction process*: Twomey, 1996), actually occur. We know that they evolve as constant, dynamic processes, contributing to unique, and sometimes unpredictable, ways of building knowledge. However, given the structure of current educational programs, observation resulting from direct contact with the student is severely limited with respect to the full 24-hour day. Most of the learning process is intractable to the instructor. An automated tool allowing her to *evidence* the learning process, for subsequent (i.e. virtual) personalized tutoring, would thus be desirable. Evidence that such phenomena is actually occurring could be detected by a *Temporal Inference Engine* (TIE) working around the clock, on a distributed media like the Internet. This tool could then be used to help her visualize the learning history of any student, in graphical (VRML-type), temporal (the student entered lesson A *before* lesson B *after* she completed assignment C), and cognitive (she retained the concept of tangent after she abstracted the 3D spatial notion of line), fashion, thus allowing her to *coach* the students more efficiently, and *personally*. A *Constructivist Animated Arena* (CAA: Espinosa & Ramos, 1999) is a learning studio tool that lets the student wander at her own pace so that the goals are reached in [properly limited] holistic manners, which the TIE constantly scans and logs, so that "smart" (not intelligent) monitoring fit well, using temporal modal logic. In a recent publication, Self and Akhras (Self & Akhras, 2000) outline four principal aspects in a comprehensive view of learning from the Constructivist standpoint. These are:

- Context (the social environment in which learning takes place).
- Activity (heavy interaction between the student and the domain studio).
- Cognitive Structures (interpretation of previously constructed knowledge).
- Time-extension (reference framework for the construction to take place).

It is noteworthy that the characterization of the learning process is being tacked by merging human factors such as the context and activity areas, with more philosophical ones such as the cognitive science and reasoning over time structures, specially since many people around the world are reporting that learning actually takes place in environments which allow students to interact among themselves, in situations where the instructor is virtually present, and in virtual scenarios where a strong emphasis on social application context is added to the domain knowledge (Willis & Oman, 2000). We view our CAA, or learning studio, work as covering all four aspects reported by Self and Akhras, but specifically the time-extension and the cognitive structures ones. The reason is that we place special interest in reasoning for incomplete, or flawed, but pedagogically relevant, data. Cognitive structure interpretation comes in handy in these cases, because we will adhere to the Constructivist thesis that "...all observation involves interpretation and that interpretation is influenced by the categories or concepts into which we map or encode our perceptions" (Luger, et. al, 1994). Although this work is not mainstream on interpretation, we make use of a simple scheme to achieve a basic version of it. Section 4 deepens into temporal logics and their implementation in our project as a standing example of direct observation and mapping upon a CAA.

This paper presents partial, and simplified, results of actual classroom behavior upon using our software, and attempts to demonstrate that a mixed approach to virtual education accounts for better results when modeled as CAA. The *Temporal Information Measurement Instrument* (TIMeI) does not attempt to exhibit intelligent behavior. Rather, it concentrates on its role as a TIE that provides useful information to a computerized tutor, or to the human instructor. TIMeI was implemented on the WWW using Java and VRML, plus an inference engine written in Visual Basic. The end-result is the *Constructivist and Open Temporal Inductive Math Environment* (COTIME) program, a Java-VRML system currently used in the High School program at the Montrerrey Institute of Technology in Mexico City. We provide conclusions, limitations on our work, and future trends we will follow using this new technology.

2 TEMPORAL HOLES IN INSTRUCTIONAL DESIGN

We now proceed to explain our arguments for using time as the premier ontological vehicle for student learning characterization. As said in the previous section, our reference framework for characterizing the learning process is based on a time-continuum. Consider the Instructional Graph (IG) in Figure 1. Let an interval within an IG be defined by two vertices (i.e. lessons). By making use of Allen's Temporal Logic Relational Operators (Pelavin, 1986), the following holds:

$$\begin{aligned}&\{L_1 before L_2 \bullet before = t_0\}\wedge \\ &\{L_1 before L_3 \bullet before = t_1\} \qquad \bullet = \text{"}where\text{"}\end{aligned} \quad [2.1]$$

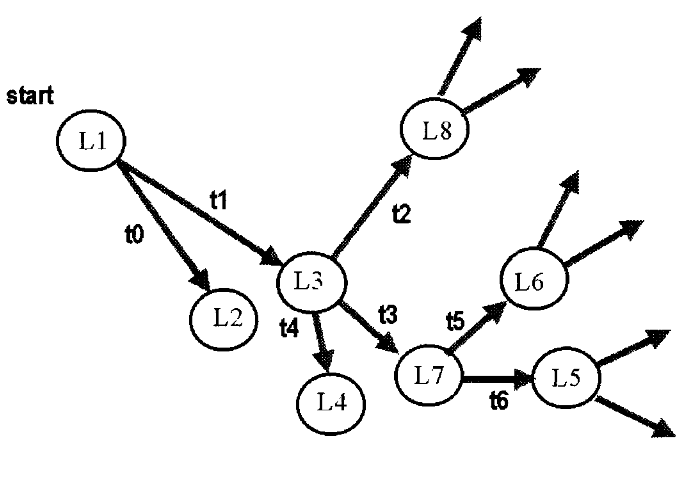

Figure1: Temporal holes in Instructional Design.

That is, the temporal description lies within the relation between lessons, so we may monitor when a student has finished a lesson, assuming knowledge and skill acquisition, and passed on to the next. However, the following *does not hold* :

$$\begin{aligned}&\{L_3 before L_8 \bullet before = t_2\} \wedge \{L_3 before L_7 \bullet before = t_3\} \wedge \\ &\{(a_1, a_2, a_3, \ldots, a_k \in Actions) during L_3\}\end{aligned} \qquad [2.2]$$

Actions are interpreted as low-level *computer events* taking place as the student makes use of a lesson. We consider low level actions events such as mouse clicks and drags, as described in (Adelheit, Gulla & Thiel, 1997). Now consider that:

$$\begin{aligned}&taughtby\,(L_3, L_1, t_1) \wedge taughtby\,(L_2, L_1, t_0) \wedge \\ &usedby\,(L_3, L_8, t_2) \wedge usedby\,(L_3, L_1, t_3) \wedge \\ &\langle L_1 (o) L_3\rangle \wedge \langle L_3 (b) L_7\rangle \wedge \langle L_3 (b) L_4\rangle \wedge \langle L_3 (b) L_8\rangle \wedge \langle L_2 (o) L_3\rangle\end{aligned} \qquad [2.3]$$

The temporal relationship

$$\langle L_i (R) L_f \bullet R = \{eq, b, a, d, di, o, oi, m, mi, s, si, f, fi\}\rangle$$

between vertices depicts a structured order of events taking place within the context of the graph. These refer to two or more intervals of time and their occurrence with respect to each other. Let *(t,u)* be fixed points (i.e. instants) in time:

1. (t,u) before (b) (v,w) if u<v.
2. (t,u) meets (m) (v,w) if u=v.
3. (t,u) overlaps (o) (v,w) if t<v<u<w.
4. (t,u) starts (s) (v,w) if t=v & u<w.
5. (t,u) during (d) (v,w) if v<t & u<w.
6. (t,u) finishes (f) (v,w) if v<t & u=w.
7. (t,u) equals (e) (v,w) if t=v & u=w.
8. (t,u) after (a) (v,w) if v>u.
9. (t,u) meets include (mi) (v,w) if u=w.
10. (t,u) overlaps include (oi) (v,w) if v>t & u<w.
11. (t,u) starts include (si) (v,w) if t=v & u>w.
12. (t,u) during include (di) (v,w) if v>t & u>w.
13. (t,u) finishes include (fi) (v,w) if v>t & u=w.

The model was first described in (Allen & Koomen, 1983) and later completed in (Pelavin & Allen, 1986). In our case, consider $\langle L_2 (o) L_3\rangle$. This is http://www.springer.com/978-0-7923-7508-1

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