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Towards a Framework for Developing Authentic Constructivist Learning Environments in Semantically Rich Domains

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Abstract

Semantically rich domains require operative knowledge to solve complex problems in real-world settings. These domains provide an ideal environment for developing authentic constructivist learning environments. In this paper we present a framework for the development of authentic learning environments for such domains.

1. Introduction

This paper focuses on learning that occurs in professional problem solving domains that require very high level of skill. In some sense, these domains are characterized by knowledge that is "operative" as the professionals are required to do work in real settings. This paper presents a framework that serves as the foundation for conceptualizing the development of authentic constructivist environments in such domains.

2. Framework

Lave and Wegner in their influential work in situated learning points out that, "…Learning occurs through centripetal participation in the learning curriculum of the ambient community." [1] Where the learning curriculum consists of "…situated opportunities (thus, including exemplars of various sorts often thought of as "goals")" [2]

This paper presents a framework that allows one to conceptualize the various aspects of the "learning curriculum" that consists of these situated opportunities and what are the general parameters that govern the construction of authentic learning environments based on these principles.

The primary components of this framework (derived from [3]) are shown in Figure 1.

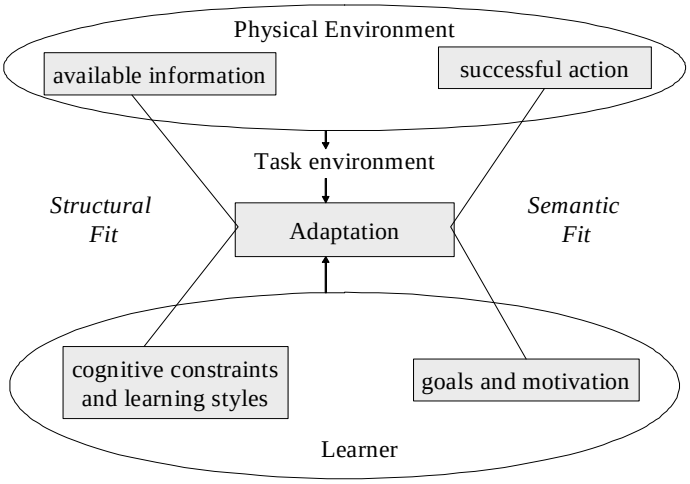

Figure 1. Framework for developing authentic constructivist learning environments

Briefly, the *Physical environment* is a description of the objectively observable characteristics (e.g., a disease or defect). The available information part of the physical environment may also consist of artifacts such as books, manuals, databases that exist as well as interaction with peers, experts and teachers. Specific characteristics of the environment require specific actions by the learner (e.g., diagnosis or repair). A task can only be performed by a learner because the information in the task is lawfully related to some physical occurrence [4].

The *Task Environment* is the subset of the physical environment that is relevant to a class of agents (e.g., surgeons). The *Adaptation* is the primary construct in this framework and represents what is "learnt" under the constraints of the *Task Environment* and the constraints from the learner. The constraints on the learner may contain cognitive constraints (e.g., short-term memory, processing capabilities [5]) and learning styles (e.g., holistic,

analytical,, field independent vs. field dependent [6] or based on theory of multiple intelligences [7], for example) on one side and goals and motivation on the other.

The first key construct in the framework is the *Adaptation* itself. *Adaptation* is a construct that develops under the constraints of the *Task Environment* and the learner (this is similar to Simon's notion of *Adaptation* as the interface between the outer and inner environment [8]).

Adaptation, however, does not exist inside the "head" or "mind" of the learner. It is a construct that represents what evolves as a set of routines (including asking for and retrieving information, for example) or dynamics that allow the learner to be "Fit" for the particular *Task Environment.*

The second key construct of the framework is the concept of "Fit" (this is not the same as the evolutionary biology's notion of a fit, but it describes a psychological fit). Loosely, the fit describes how well a Learner is adapted to the *Task Environment* (e.g., how good is the surgeon?). Fit can be classified into two dimensions; semantic and structural.

The semantic dimension is a measure of how well the learner's actions are acceptable in the particular environment (e.g., how well are surgeons operations received in the physical world – how many patient's actually die under her care). Hence the semantic fit is primarily related to how well the goals and the intentions of the learner are realized in the actions she takes in the physical environment.

The structural dimension of fit describes how closely do the cognitive constraints and learning styles of the learner "match" to the information present in the environment (e.g., does the surgeon accept a particular type of surgery as suited to her skills). Manifestation of failure of structural fit occurs when, for example, an individual refuses to accept the information provided in the environment as "valid" for their task environment.

3. Authentic Learning Environments

Authentic learning environments in the constructivist tradition are situations that allow a learner to create their own personal knowledge in a particular task environment. In a way, an authentic learning environment is a surrogate to the actual problem-solving environment.

An authentic learning environment can, therefore, be simply described as a manifestation of a "learning curriculum" as describes by Lave and Wegner. In terms of the framework, the learning curriculum, then, is simply a set of situated opportunities that allow the *Adaptation* to eventually attain a high degree of fit between the *Task Environment* and the learner.

The design of a good authentic learning environment, therefore, consists of creation of an appropriate set of situated opportunities. Each situated opportunity is described by 4-tuple <I, A, C, G> where

I: Information in the environment
A: Successful actions in the environment
C: Cognitive constraints and learning styles of the learner
G: Goals and intentions of the learner

A successful authentic environment has to create enough (and the right) situated opportunities to ensure that the *Adaptation* that arises for a specific learner has both a high structural as well as a semantic fit.

A fundamental problem that arises with using authentic environments is their validity. In other words, the situated opportunities created by

within an authentic environment are simply a surrogate for the real environment (e.g., surgery room as opposed to the simulator). How does, for example, one ensure that the *Adaptation* thus evolved within the authentic environment will in fact transfer to the real environment?

Now we look at various dimensions of an authentic learning environment and show how the framework can provide conceptual footing in each case. A particular instance of an authentic constructivist environment can be described based on the following dimensions

1. The Pedagogical Design
2. The Architecture
3. The Environmental Context
4. What is Learnt

4. Pedagogical Design

Some commonly used Pedagogical designs for "authentic" learning environments in the constructivist tradition are given below [9] and [10]

- **Problem-based Learning** (PBL) - In PBL, a convincing scenario problem (scenario) is created where learners are supported by stories as told by various actors. The primary premise behind these environments is to allow the learners to fail in a "safe" context and to receive feedback as a third-person.
- **Distributed Problem-Based Learning** (DPBS) brings the additional element of a group of individuals using the network as a medium to work on and solve a common problem.
- **Inquiry-based learning** (IBL) is one variant of PBL that poses ill-structured tasks to the students.
- **Role-Play Simulation and Game-based Learning** (RSL) creates situations where learners take on the role-profiles of various characters in contrived educational games.
- **Case Studies based Learning** (CSBL) use actual events to force students to "practice" on actual data in a safe environment.
- **Critical Incidence-based Learning** (CIBL) occurs when learners engage in reflections on critical events from their workplace.
- **Project-based Learning (PRBL)** engages students in designing and creating products that meet authentic needs.

No matter what the manifestation of the pedagogical design of an authentic environment, each has to pay particular attention to how and why the situated opportunities thus created are authentic. For example, In PBL, a problem consist of the information presented in the environment (I), the feedback provided by the stories in fact guides the learner on what is successful action (A) through failure and certainly the problems have to be consistent with the goals of the learner (G) as well as the cognitive constraints. The DBPS simply adds additional sources of information (I) that learner can access.

Critical Incidence-based Learning is particularly interesting in this context in that it is related to low-base rate tasks [11]. That is, environments where the incidence of situated opportunities is very rare (e.g., earth quakes). In this case, the problem to be solved becomes mostly the generation of an appropriate number of situated opportunities, so that the *Adaptation* can attain a high degree of fit.

Similarly, in CSBL, the emphasis is not so much on creating the right information (I). Neither, is the

appropriateness of actions an issue (A). The emphasis really has to be how well the fit can occur with learner's cognitive constraints and learning styles as well as the goals.

5. Architecture of Authentic Environment

The architecture of an authentic environment specifies the various components that must exist in a learning environment or a computer manifestation of it. [16] provides a general characterization of the constructivist learning environments. The components needed for such environments are

- **Problem/project space**- The learners are presented with an interesting, relevant and engaging problem. This- is simply the creation of one situated opportunity.

- **Related Cases-** When expecting learners to solve problems, they must be provided with a set of related experiences on which the learner's can draw. These represents a set of situated opportunities similar to the one being presented.
- **Information Sources-** Providing learners with information they need help with in a timely manner. This simply stresses the information component (I) of the situated opportunity.
- **Cognitive (knowledge) construction tools-** Tools that support the learner's abilities to solve the tasks at hand. These are a part of the physical environment (e.g., a paper and a pencil, a calculator, a utility program) if the fit requires that the Learner's cognitive constraints (C) need to be augmented to achieve an appropriate fit.
- **Conversation (knowledge-negotiation) tools-** Tools to support collaboration. These are a part of the physical environment, if accessing information (I) or successful action (A) requires external conversations.
- **Social/contextual support-** Physical, organizational, political and cultural aspects of the environment. This can be primarily related to the motivation and goals (G) of the learner.

6. Context of Learning

Authentic learning environments exist in a context. [12] describes the environmental contexts of an intelligent tutoring system. A description of these contexts can also be applied to an authentic learning environment. [12] divides the context into seven categories.

- **Student** (natural abilities, learning styles and motivation)
- **Peers**
- **Social Environment** (social values, institutional values, evolution of common metaphors)
- **Teacher** (teaching styles, personality attributes)
- **Discipline** (homogeneity, operational/conceptual, physical/virtual, teaching traditions, levels)
- **Characteristics of knowledge** (operational, causal, contextual)
- **Characteristics of medium** (hardware, software and communication capabilities).

From the perspective of the framework, these categories roughly map as shown in Figure 2.

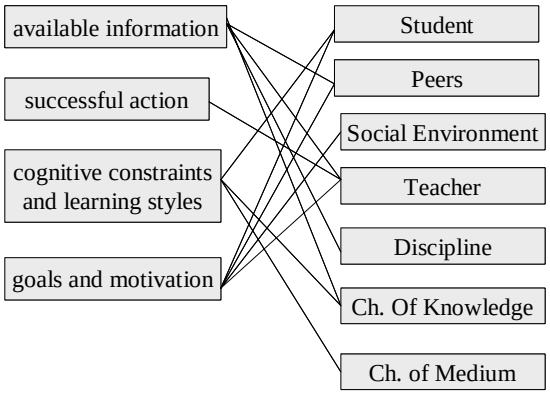

Figure 2. Relationship between Framework and Context

It is interesting to note that Teacher or the teaching style maps mostly to providing the available information (what it provided to the student), successful action (guiding through assessment) and motivation. Most traditional instructional theories such as Gagne's nine steps [13], John Keller's ARCS model [14], or Merrill's ITT [15] can in fact be used for creating these parts of situated opportunities as they are tied to information (I) and successful action (A) alone and are all concerned with how to enable (as goals are prescribed by the teacher) a student to do something.

5. What is Learnt

One of the critical components of the framework is the nature of the *Adaptation* that occurs as a result of interacting with the information, and carrying out actions in the physical environment.

The *Adaptations* that develop will be unique to a particular individual learner. While *Adaptation* is an abstract entity, it can be described. In the context of semantically rich domains, descriptions of these *Adaptations* can take the form of successful arguments that these learners can generate. These arguments can be constructed from five basic types of backings [17].

- **Type 1** – This is based on analytic truths; the interesting property is that the all actions preserve global criteria of rationality such as consistency, soundness and completeness.
- **Type 2** – This is based on empirical judgments where the actions are constrained to consist of consensus among groups of individuals.
- **Type 3** – This is based on complementary representations of a problem and actions are constrained by agreement within complementary analytic representations and empirical judgments.
- **Type 4** – This is based on complementary representations of a problem and the actions are based upon resolving conflicts within these.
- **Type 5** – This is based "systems of knowing" that lead the process such that actions are constrained by self-reflection.

The *Adaptation* for a highly skilled individual can be described using a complex combination of these arguments across diverse domains including medicine, chess, experimental design, VLSI manufacturing, and fraud-detection [17].

Bloom's [19] original description of the types of learning (Cognitive, Affective and Psychomotor) comes close to serving as an appropriate language for a description of such *Adaptations*. For example, the category of "Synthesis" as described by

Bloom [18] consists of building a structure or pattern from diverse elements. The keywords that describe this activity are combines, plans, creates etc. The *Adaptation* for a skilled individual engaged in a semantically rich domain such as statistical experimental design [17], however, contains many types of "Synthesis".

For example, the individual constructs an initial conceptualization of the client's problem, subsequently she constructs a refined quasi-statistical representation (and re-representation) of the client's problem, and then she constructs an appropriate design type and finally a specific design.

The goal of carrying out each one of these "Synthesis" steps actually are achieved by paying attention to very different types of information and by using various types of qualitatively different backings. For example, conceptualization of a client's quasi-statistical representation of the problem is based on a Type 3 backing (see Figure 3) while the construction of an appropriate design type is Type 4. Derivation of a particular design uses Type 1 backing.

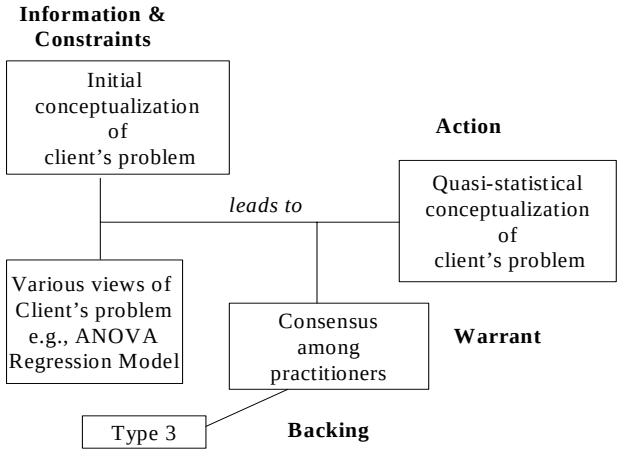

Figure 3. An example description of an Adaptation tied to a particular Goal

Hence the argument structure described in [17] presents a refined language to describe specific individual *Adaptations* for semantically rich domains as opposed to the classification based on keywords (e.g., combines, creates etc.) presented by Bloom to describe what is learnt.

Conclusion

In this paper we have presented a framework for analyzing the development of authentic constructivist learning environments for semantically rich domains. We have shown how and why this ecological framework maps onto the various views one takes when developing an authentic constructivist environment. Although the basic framework has been successfully applied to thinking about complex problem solving in semantically rich domains, its use in developing constructivist environments is very new. Like all frameworks, its true utility will be realized based on its application to better construction and evaluation of authentic learning environments.

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