Constructivist Learning Environments on the Web:
Engaging Students in Meaningful Learning

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An antidote for reproductive learning is to engage learners in active manipulative), constructive, intentional, complex, authentic, cooperative (collaborative and conversational), and reflective learning activities. Those characteristics are the goal of constructivist learning environments (CLEs). This paper presents a model for designing CLEs, which surround a problem/project/issue/question (including problem context, problem representation space, and problem, manipulation space) with related cases (to supplant learners' lack of experiences and convey complexity), information resources that support knowledge construction, cognitive tools, conversation and collaboration tools, and social-contextual support for implementation. These components are supported by instructional supports, including modeling, coaching, and scaffolding. This model is directly applicable to web-based learning. Examples of web-CLEs will be demonstrated in the presentation.

Model for Designing Constructivist Learning Environments

Constructivist conceptions of learning assume that knowledge is individually constructed and socially co-constructed by learners based on their interactions in the world. The meaning that learners construct depends on their needs, beliefs, and prior knowledge. This paper presents a model for designing constructivist learning environments (CLEs) that engage learners in meaning making based on constructivist assumptions(Duffy & Jonassen, 1992; Jonassen, 1991, 1995, 1996a; Jonassen, Peck, & Wilson, 1998; Savery & Duffy, 1995).

The model for designing CLEs (Fig. 1) illustrates their essential components. The model conceives of a problem, project, question, or issue as the focus of the environment, with various interpretative and intellectual support systems surrounding it. The goal of the learner is to interpret and solve the problem/complete the project/answer the question/resolve the issue. Related cases and information resources support understanding of the problem and suggest possible solutions; cognitive tools help learners to interpret and manipulate aspects of the problems; conversation/collaboration tools enable communities of learners to negotiate and co-construct meaning for the problem; and social/contextual support systems help teachers to implement the CLE. The remainder of this paper describes these elements.

1. Question/Case/Problem/Project

The focus of any CLE is the question or issue, the case, the problem, or the project that learners attempt to solve or resolve. It constitutes the learning goal. The fundamental difference between CLEs and objectivist instruction is that here the problem drives the learning. In objectivist instruction, problems function as examples or applications of the concepts and principles previously taught. Students learn domain content in order to solve the problem, rather than solving the problem to apply the learning.

CLEs can be constructed to support question/issue-based, case-based, project-based, or problem-based learning. Question- or issue-based learning begins with a question with uncertain or controversial. In case-based learning, students acquire knowledge and requisite thinking skills by studying cases (e.g. legal, medical, social work) and preparing case summaries or diagnoses. Case learning is anchored in authentic contexts; learners must think manage complexity and think like practitioners (Williams, 1992). Project-based learning focuses on a relatively long-term, integrated units of instruction where learners focus on complex projects consisting of multiple cases. They debate ideas, plan and conduct experiments, and communicate their findings (Krajcik, Blumenfeld, Marx, & Soloway, 1994). Problem-based learning (Barrows & Tamblyn, 1980) integrates courses at a curricular level, requiring learners to self-direct their learning while solving numerous cases across a curriculum. Case-, project-, and problem-based learning represent a continuum of complexity, but all share the same assumptions about active, constructive, and authentic learning. CLEs can be developed to support each of these, so for purposes of this chapter, which seeks to present a generic design model, I will refer to the focus of the CLEs generically as a problem.

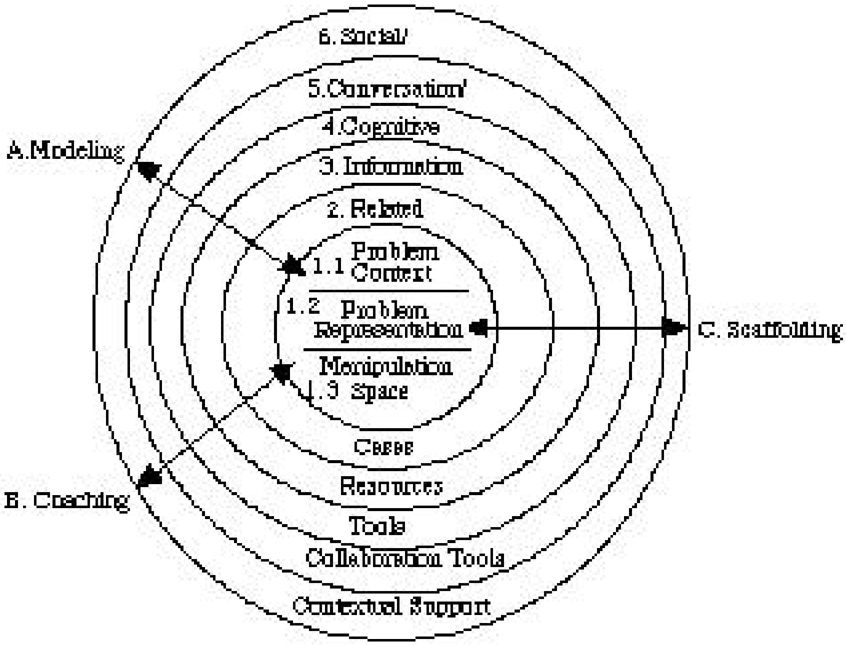

Fig. 1. Model for designing constructivist learning environments.

It is important to provide interesting, relevant, and engaging problems to solve. The problem should not be overly prescribed. Rather, it should be ill-defined or ill-structured, so that some aspects of the problem are emergent and definable by the learners. Ill-structured problem have unstated goals and constraints and have multiple solutions, solution paths, or no solutions at all. You need to decide if your students possess prerequisite knowledge or capabilities for working on the problem that you identify. Problems in CLEs need to include three integrated components: the problem context, the problem representation or simulation, and the problem manipulation space. In order to develop a CLE, you must represent each in the environment.

1.1. Problem Context

An essential part of the problem representation is a description of the context in which it occurs. The same problem in different social or work contexts is different. CLEs must describe in the problem statement all of the contextual factors that surround a problem. You must describe the physical, sociocultural, and organizational climate surrounding the problem. Where and in what time frame does it occur? What physical resources surround the problem? What is the nature of the business, agency, or institution in which the problem occurs? What do they produce? Provide annual reports, mission statements, balance sheets, profit and loss statements if they appropriately describe the situation. What is the history of the setting? This information should be made available to learners in order to understand the problem.

What are the values, beliefs, sociocultural expectations, and customs of the people involved? Who sets policy? What sense of social or political efficacy do the members of the setting or organization feel? What are the skills and performance backgrounds of performers? You can convey this information in stories or interviews with key personnel in the form of audio or video clips. It is the community of participants who are define what learning occurs in a context.

1.2 Problem Representation

The representation of the problem must be interesting, appealing, and engaging. It must perturb the learner. Use high-quality video scenarios or virtual worlds for introducing the problem and engaging learners. An effective, low-tech method for representing problems is narrative. The problem context and problem representation become a story about a set of events which leads up to the problem that needs to be resolved. Effective examples of narrative forms of problem representations are the instructional design cases (Lindeman, Kent, Kinzie, Larsen, Ashmore, & Becker, 1996). In these cases, characters are developed who interact in realistic ways to introduce the case problem. Stories are also the primary means of problem representation and coaching in goal-based scenarios (Schank et al, 1994). The problem presentation simulates the problem in a natural context. Stories are a natural means for conveying them. The problem and its context and representation should be authentic. Some designers insist that authentic refers to supporting the performance of specific real-world tasks. Most believe that authentic means that learners should engage in activities which present the same “type” of cognitive challenges as those in the real world (Honebein, et.al. 1993; Savery & Duffy, 1996), that is, tasks which replicate the particular activity structures of a context.

Activity structures rely on the sociohistorical context of activity theory (Leontev, 1979) which focuses on the activities that community members engage in, the goals of those activities, the physical setting that constrains and affords certain actions, and the tools that mediate activity. Activity theory provides an effective framework for designing CLEs (Jonassen & Rohrer-Murphy, 1998).

1.3 Problem Manipulation

In order for learners to engage in meaningful learning, they must manipulate something — construct a product, manipulate parameters, make decisions — affect the environment in some way. Activity theory describes the transformational interactions between the learner, the object that the learner is acting on, and the signs and tools which mediate that interaction. The problem manipulation space provides the objects, the signs, and tools required for the learner to manipulate the environment. Why? Students cannot assume any ownership of the problem unless they know that they can affect the problem situation in some meaningful way.

The form of the problem manipulation space will depend on the nature of the activity structures the CLE is engaging, however, it should provide a physical simulation of the real-world task. Learners are directly engaged by the world they explore, because they can experiment and immediately see the results of their experiment. Problem manipulation spaces are causal models that enable students to test the effects of their manipulations, receiving feedback through changes in the physical appearance of the physical objects they are manipulating or in the representations of their actions, such as charts, graphs, and numerical output. They should allow learners to manipulate objects or activities, be sensitive to environment changes in realistic ways to learner manipulations, be realistic, and provide relevant feedback.

In creating problem manipulations spaces, it is not always necessary for learners to manipulate physical objects or simulations. It may be sufficient merely to generate a hypothesis or intention to act and then to argue for it. When engaging learners in solving ill-structured problems, requiring learners to articulate their solutions to problems and then develop a coherent argument to support that solution is sufficient (Jonassen, 1997).

2. Related Cases

Understanding any problem requires experiencing it and constructing mental models of it. What novice learners lack most are experiences. This lack is especially critical when trying to solve problems. So, it is important that CLEs provide access to a set of related experiences that novice students can refer to. The primary purpose of describing related cases is to assist learners in understanding the issues implicit in the problem representation. Related cases in CLEs support learning in at least two ways: by scaffolding memory and by representing complexity.

The lessons that we understand the best are those in which we have been most involved and invested the greatest amount of effort. Related cases can scaffold memory by providing representations of experiences that learners have not had. They cannot replace learners' involvement, but they can provide referents for comparison. When humans first encounter a situation or problem, they naturally first check their memory for similar cases that they may have solved previously (Polya, 1957). If they can recall a similar case, they try to map the previous experiences and its lessons onto the current problem. If the goals or conditions match, they apply their previous lesson. By presenting related cases in learning environments, you are providing the learners with a set of experiences to compare to the current problem or issue. Learners retrieve from related cases advice on how to succeed, pitfalls that may cause failure, what worked or didn't work, and why it didn't (Kolodner, 1993). They adapt the explanation to fit the current problem.

In order to provide a rich set of related cases that will help learners to solve the current one, it is necessary to collect set of cases that are representative of the current one (those with similar contexts, solutions, or results), identify the lessons that each can teach, characterize the situations in which each case can teach its lesson, and develop an index and represent its features in a way that allows cases to be recalled (Kolodner, 1993).

Related cases also help to represent complexity in CLEs by providing multiple perspectives, themes, or interpretations to the problems or issues being examined by the learners. An important model for designing related cases in CLEs, cognitive flexibility theory, provides multiple representations of content in order to convey the complexity that is inherent in the knowledge domain (Jonassen, 1993; Spiro et al, 1987). Stress the conceptual interrelatedness of ideas and their interconnectedness by providing multiple interpretations of content. Use multiple, related cases to convey the multiple perspectives on most problems. In order to enhance cognitive flexibility, it is important that related cases provided a variety of viewpoints and perspectives on the case or project being solved.

3. Information Resources

In order to investigate problems, learners need information about the problem in order to construct their mental models and formulate hypotheses that drive the manipulation of the problem space. So, when designing CLEs, you should determine what kinds of information the learner will need in order to understand the problem. Rich sources of information are an essential part of CLEs. CLEs should provide learner-selectable information just-in-time. CLEs assume that information makes sense only in the context of a problem or application. So, determine what information learners need to interpret the problem. Some of it is naturally included in the problem representation. Other relevant information banks and repositories should be linked to the environment. These may include text documents, graphics, sound resources, video, animations that are appropriate for helping learners comprehend the problem and its principles. The World Wide Web (WWW) is the default storage medium, as powerful new plug-ins enable users to access multimedia resources from the net. Beware, simply pointing to WWW resources may provide serious to thinking necessary for solving the problem

4. Cognitive (Knowledge Construction) Tools

If CLEs present complexity, novel, and authentic tasks, you will need to support learners' performance of those tasks. In order to do that, you must identify the activity structures that are required to solve the problem. Which of those skills are likely to be possessed by the learners? For those that are not, you must provide cognitive tools that scaffold the learners' abilities to perform those tasks.

Cognitive tools are generalizable computer tools that are intended to engage and facilitate cognitive processing (Kommers, Jonassen, & Mayes, 1992). They are intellectual devices that are used to visualize (represent), organize, automate or supplant information processing. Some cognitive tools replace thinking while others engage learners in generative processing of information that would not occur without the tool. Cognitive tools support learners in a variety of cognitive processing tasks. For example, visualization tools help learners to construct those mental images and visualize activities. Numerous visualization tools provide reasoning-congruent representations that enable learners to reason about objects that behave and interact (Merrill, Reiser, Bekkalaar, & Hamid, 1992). Examples include the graphical proof tree representation in the Geometry Tutor (Anderson, Boyle, & Yost, 1986); the Weather Visualizer (colorizes climatological patterns); the Climate Watcher (colorizes climatological variable) (Edelson et al, 1996).

As students study phenomena, it is important that they articulate their understanding of the phenomena. Modeling tools provide knowledge representation formalisms that constrain the ways that learners think about, analyze, and organize phenomena and provide an environment for encoding their understanding of those phenomena. For example, creating a knowledge database or a semantic network requires learners to articulate the range of semantic relationships among the concepts that comprise the knowledge domain. Expert systems engage learners in articulating the causal reasoning between objects or factors that predict outcomes in a domain (Jonassen, 1996a). Modeling tools help learners to answer "what do I know" and "what does it mean" questions. As a CLE designer, you must decide when learners need to articulate what they know and which formalism will best support their understanding.

Complex systems contain interactive and interdependent components. In order to represent the dynamic relationships in a system, learners can use dynamic modeling tools for building simulations of those systems and processes and testing them. Programs like Stella use a simple set of building blocks to construct a map of a process. Learners supply equations that represent causal, contingent, and variable relationships between the variables identified on the map. Having modeled the system, Stella enables learners to test the model and observe the output of the system in graphs, tables, or animations. At the run level, students can change the variable values to test the effects of parts of a system on the other. Modeling phenomena may also call on dynamic modeling tools, such as Model It (Spitulnik, Studer, Finkel, Gustafson, & Soloway, 1995) which scaffolds the use of mathematics by providing a range of qualitative relationships that describe the quantitative relationships between the factors or allowing them to enter a table of values that they have collected.

In many environments, performing repetitive, algorithmic tasks can rob cognitive resources from more intensive, higher-order cognitive tasks that need to be performed. Therefore, CLEs should automate algorithmic tasks in order to offload the cognitive responsibility for their performance. For example, in business problem solving environments, we have provided spreadsheet templates of problems for learners to test their hypotheses about levels of production, inventory, and sales. Most forms of testing in CLEs should be automated so that learners can simply call for test results. Generic tools such as calculators or database shells may be embedded to help learners organize the information that they collect. Most CLEs provide notetaking facilities to offload memorization tasks. Identify in the activity structures those tasks with which learners are facile and may distract reasoning processes and try to find a tools which supports that performance.

5. Conversation and Collaboration Tools

Contemporary conceptions of technology-supported learning environments assume the use of a variety of computer-mediated communication to support collaboration and conversation among communities of learners (Scardamalia, Bereiter, & Lamon, 1994). Why? Learning most naturally occurs not in isolation but by teams of people working together to solve problems. CLEs should provide access to shared information and shared knowledge building tools to help learners to collaboratively construct socially shared knowledge. Problems are solved when groups work toward developing a common conception of the problem, so their energies can be focused on solving it. Conversations may be supported by discourse communities, knowledge-building communities, and communities of learners.

Scardamalia and Bereiter (1996) argue that schools inhibit, rather than support, knowledge building by focusing on individual student abilities and learning. In knowledge building communities, the goal is to support students to "actively and strategically pursue learning as a goal (Scardamalia, Bereiter, & Lamon, 1994, 201). To enable students to focus on knowledge construction as a primary goal, Computer-Supported Intentional Learning Environments (CSILEs) enable students to produce knowledge databases so that their knowledge can "be objectified, represented in an overt form so that it could be evaluated, examined for gaps and inadequacies, added to, revised, and reformulated" (p. 201). CSILEs provide a medium for storing, organizing, and reformulating the ideas that are contributed by each of the members of the community. The knowledge base represents the synthesis of their thinking, something they own and for which they can be proud.

CLEs can also foster and support communities of learners (COLs). COLs emerge when students share knowledge about common learning interests. Newcomers adopt discourse structure, values, goals, and beliefs of community (Brown, 1994). COLs can be fostered by having the participants conduct research (reading, studying, viewing, consulting experts) and share information in the pursuit of a meaningful, consequential task (Brown & Campione, 1996). Many of these learning community environments support reflection on the knowledge constructed and the processes used to construct it by the learners. Scaffolded environments that support COLs include the Collaboratory Notebook (O'Neill & Gomez, 1994); CaMILE (Guzdial, Turns, Rappin, & Carlson, 1995) and the Knowledge Integration Environment (Bell, Davis, & Linn, 1995). Their common belief is that learning revolves around learners' conversations about what they are learning, not teacher interpretations.

In order to support collaboration among groups of learners, who may be either co-located or at a distance, CLEs should provide for and encourage conversations about the problems and projects the students are working on. Students write notes to the teacher and to each other about questions, topics, or problems that arise. Textualizing discourse among students makes their ideas appear to be as important as each other's and the instructor's comments (Slatin, 1992). When learners collaborate, they share the same goal — to solve the problem or reach some scientific consensus about an issue.

6. Social/Contextual Support

Throughout the history of instructional design and technology, projects have failed most often because of poor implementation. Frequently they tried to implement their innovation without considering important physical, organizational, and cultural aspects of the environment into which the innovation was being implemented. In designing and implementing CLEs, accommodating contextual factors is important to successful implementation. It is also necessary to train the teachers and personnel who will be supporting the learning, and finally train the students who will be learning from the environments. The CoVis project (Edelson et al, 1996) supports teachers by sponsoring workshops and conferences where teachers can seek help from and establish a consensus with the researchers. Questions can be posed by teachers, which are answered by peer teachers or technical staff.

Supporting Learning in CLEs

Students perform a variety of learning activities in CLEs including exploration and manipulation of the environment, articulation of what they have learned (speculation, conjecturing, hypothesize testing, and reflection on what they did.

Exploring attributes of the problem includes investigating related cases for similarities, and perusing information resources to find evidence to support. The most important outcomes of exploration are goal-setting and managing the pursuit of those goals (Collins, 1991)

The cognitive activities engaged by CLEs include speculating and conjecturing about effects, manipulating the environment, observing and gathering evidence, and drawing conclusions about those effects. Most of these activities require reflection-in-action (Schon, 1982). Skilled practitioners often articulate their thoughts while performing, that is, reflect-in-action.

In order to support exploration, articulation, and reflection in CLEs, it is necessary to support learners by modeling, coaching, and scaffolding these activities.

A. Modeling

Modeling is the most commonly used instructional strategy in CLEs. Two types of modeling exist: behavioral modeling of the overt performance and cognitive modeling of the covert cognitive processes. Behavioral modeling in CLEs demonstrate how to perform the activities identified in the activity structure. Cognitive modeling articulates the reasoning (reflection-in-action) that learners should use while engaged in the activities.

Carefully demonstrate each of the activities involved in a performance by a skilled (but not an expert) performer. When learners need help in a CLE, they might press a "Show Me" or a "How Do I Do This?" button. Modeling provides learners with an example of the desired performance. It is important to point out each of the discrete actions and decisions involved in the performance, so that the learner is not required to infer missing steps. A widely recognized method for modeling problem solving is worked examples.

Worked examples include a description of how problems are solved by an experienced problem (Sweller and Cooper, 1985). Worked examples enhance the development of problem schemas and the recognition of different types of problems based on them. Using worked examples redirects the learner's attention away from the problem solution and toward problem-state configurations and their associated moves. Worked examples should be augmented by articulation of the reasoning (reflection-in-action) by the performer.

As an experienced performer models problem solving or project skills, s/he should also articulate the reasoning and decision making involved in each step of the process, that is, modeling the covert as well as the overt performance. Record the performer thinking aloud while performing. Analyze the protocol in order to provide cues to the learners about important actions and processes, perhaps even elaborating on or providing alternative representations of those activities. You might also record the performer conducting a post mortem analysis or abstracted replays, where you discuss the performer's actions and decisions. An important skill is knowing how to develop arguments to support their solutions to the problem. In these cases, performers should overtly model the kinds of argumentation necessary to solve the problem. You might also consider providing reasoning-congruent visual representations (described before) generated by the skilled performer. These visual models of the objects of expert reasoning may provide rich alternative representations to help learners perceive the structure of reasoning.

B. Coaching

Modeling strategies focus on how expert performer function. The assumption of most instruction is that in order to learn, learners will attempt to perform like the model, first through crude imitation, advancing through articulating and habituating performance, to the creation of skilled, original performances. At each of these stages, learners' performances will likely improve with coaching. The role of coach is complex and inexact. A good coach motivates learners, analyzes their performance, provides feedback and advice on the performance and how to learn about how to perform, and provokes reflection and articulation of what was learned.

Coaching may be solicited by the learner. Students seeking help might press a "How am I Doing?" button. Or coaching may be unsolicited, when the coach observes the performance and provides encouragement, diagnosis, directions, and feedback. Coaching naturally and necessarily involves responses that are situated in the learner's task performance (Laffey, Tupper, Musser, & Wedman, 1997). You can include the following kinds of coaching in CLEs.

A good coach relates the importance of the learning task to the learner. In case the learners are not immediately engaged by the problem, then the CLE coach needs to provide learners a good reason for becoming engaged. Once started, the coach should boost the learners' confidence levels, especially during the early stages of the problem or project. Motivational prompts can usually be faded quickly once learners become engaged by the problem. It may be necessary to provide additional, intermittent prompts during the performance of particularly difficult tasks.

The most important role of the coach is to monitor, analyze, and regulate the learners' development of important skills. Coaching may provide *hints* and *helps*, such as directing learners to particular aspects of the tasks or reminding learners of parts of the task they may have overlooked; prompt appropriate kinds of thinking, such as suggestions to generate images, make inferences, generalize another idea, use an analogy, make up a story, generate a questions, summarize results, or draw an implication; prompt consideration of related cases or particular information resources that may help learners interpret or understand ideas; prompt the use of specific cognitive tools that may assist articulation and understanding of underlying concepts or their interrelationships; or provide feedback that not only informs the learners about the effectiveness and accuracy of their performance but also analyzes their actions and thinking.

The mental models that naive learners build to represent problems are often flawed. They often misattribute components of the problem or incorrectly connect them so they are trying to solve the wrong kind of problem. So it is necessary to perturb the learner's model. When learners see that their models do not adequately explain the environment they are trying to manipulate, they adjust or adapt the model to explain the discrepancies. Perturbing learners' understanding can be accomplished by embedding provoking questions (have you thought about...., what will happen if....., does your model explain....). It is also useful to require learners to reflect on actions they have taken (why did you....., what results did you expect...., what would have happened if.....). A simpler approach is to ask learners to confirm or clarify what did happen (why did that reaction occur...). performance, thinking, and resulting mental model.

<u>C. Scaffolding</u>

Modeling focused on the expert's performance. Coaching focused on the learner's performance. Scaffolding is a more systemic approach to supporting the learner, focusing on the task, the environment, the teacher, and the learner. Scaffolding provides temporary frameworks to support learning and student performance beyond their capacities. The concept of scaffolding represents any kind of support for cognitive activity that is provided by an adult when the child and adult are performing the task together (Wood & Middleton, 1975).

The concept of scaffolding is fuzzy and indistinct in many definitions from modeling and coaching.

For purposes of CLEs, I believe that scaffolding represents some manipulation by the system of the task itself. When scaffolding performance, the system performs part of the task for the student, supplants the student's ability to perform some part of the task by changing the nature of the task or imposing the use of cognitive tools that help the learner perform, or adjusts the nature or difficulty of the task. Whereas coaching focuses on an individual task performance, scaffolding focuses on the inherent nature of the task being performed. A learner's request for scaffolding might take the form of a "Help Me Do This?" button. When designing CLEs, consider the following kinds of scaffolds.

Learners experiencing difficulties in performing a task possess insufficient prior knowledge or readiness to perform. This suggests two separate approaches to scaffolding of learning: adjust the difficulty of the task to accommodate the learner or design the task to supplant a lack of prior knowledge, or provide alternative assessments. Designing scaffolds requires explication of the activity structure required to complete a job (using activity theory or cognitive task analysis, as described before). From the list of tasks or activities, identify those which are nor currently possessed by the learners or for which the learners are not ready (defining the learner's zone of proximal development).

Scaffolding may provide an easier task. Start the learners with the tasks they know how to perform and gradually add task difficulty until they are unable to perform alone. This will be their zone of proximal development. This form of task regulation is an example of black-box scaffolding (Hmelo & Guzdial, 1996), that which facilitates student performance but which will not be faded out while learners are using the environment. This is the kind of scaffolding that learners cannot see; the adult supporter is invisible.

Another approach to scaffolding learners performance is redesign the task in a way that supports learning, that is, supplanting task performance (Salomon, 1979). Task performance may also be supplanted by suggesting or imposing the use of cognitive tools to help learners represent or manipulate the problem. These forms of scaffolding are examples of glass-box scaffolding (Hmelo & Guzdial, 1996) because they are faded after a number of cases. Otherwise they become intellectual crutches. Learners need to be helped to perform that which they cannot do alone. Having performed desired skills, they must learn to perform without the scaffolds that support their performance.
what the solution will be like (Jonassen, 1997).

Summary

This paper has briefly described a model for designing CLEs. It has conceptually described the components of a CLE and the strategies for supporting learners' performances in them. Because of page limitations, I was unable to articulate the philosophical assumptions behind CLEs, impediments to learning from CLEs, how to evaluate CLEs, and alternative approaches to using technology to support constructive learning. Those topics will be addressed in other publications.

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