Cognitive Apprenticeship, Technology, and the Contextualization of Learning Environments

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ABSTRACT

The purpose of this electronic paper is twofold: (1) to add clarity and consistency to the notion of cognitive apprenticeship as a framework for instructional design; and (2) to view the connection between cognitive apprenticeship and computer-based learning. The paper is organized around three major sections and a conclusion. The first section examines the theoretical and philosophical backgrounds of the cognitive apprenticeship model. It explores the relationship between the traditional apprenticeship and the cognitive apprenticeship approach. The second section focuses on the various dimensions and components of cognitive apprenticeship. The third section deals with the role of technology in supporting and implementing cognitive apprenticeship as a model for designing learning environments. The conclusion outlines major benefits and challenges when implementing the cognitive apprenticeship model.

INTRODUCTION

Cognitive apprenticeship is an instructional design model which is based on current understandings of how individuals learn (Bransford, Brown, & Cocking, 2000). The term was first coined and articulated by Collins, Brown, and Newman (1989). The authors wrote:

> "We propose an alternative model of instruction that is accessible within the framework of the typical American classroom. It is a model of instruction that goes back to apprenticeship but incorporates elements of schooling. We call this model "cognitive apprenticeship" (Collins, Brown, and Newman, 1989, p. 453).

The goal of cognitive apprenticeship is to address the problem of inert knowledge and to make the thinking processes of a learning activity visible to both the students and the teacher. The teacher is then able to employ the methods of traditional apprenticeship (modeling, coaching, scaffolding, and fading) to effectively guide student learning (Collins et al., 1991). Cognitive apprenticeship supports the effective integration of academic and vocational education so students construct their own understanding of academic standards and internalize the thinking processes used to do so. This approach also includes a cognitive component which focuses on teaching the cognitive and metacognitive skills associated with a specific domain of knowledge. The cognitive and metacognitive components of learning deal with the processes and strategies used to problem solve and are used in situations which require learners to extend their knowledge to novel or complex situations outside of the classroom. By so doing, students will learn to think like technicians, scientists and mathematicians.

The authors (Collins, Brown, & Holum, 1991; Collins, Brown, & Newman,1989) as well as other researchers (Herrington & Oliver, 2000) have refined this model to the belief that useable knowledge is best gained in learning environments featuring the following characteristics:

- Authentic context that allows for the natural complexity of the real world
- Authentic activities
- Access to expert performances and the modeling of processes
- Multiple roles and perspectives
- Collaboration to support the cooperative construction of knowledge
- Coaching and scaffolding which provides the skills, strategies and links that the students are initially unable to provide to complete the task
- Reflection to enable abstractions to be formed
- Articulation to enable tacit knowledge to be made explicit
- Integrated assessment of learning within the tasks

PHILOSOPHICAL AND THEORETICAL BACKGROUND

Roots of Cognitive Apprenticeship

I believe that there are at least four notions that exert a strong influence in shaping the method of cognitive apprenticeship:

- Socio-cultural Theory of Learning
- Vygotsky's Zone of Proximal Development (ZPD)
- Situated Cognition
- Traditional Apprenticeship

Of course, the following brief overview of these notions omits many of the nuances and issues that characterize the debate over them but the goal here is to identify the fundamental tenets related to these notions. Figure 1 is a visual representation of the roots and place of cognitive apprenticeship in educational literature proposed here.

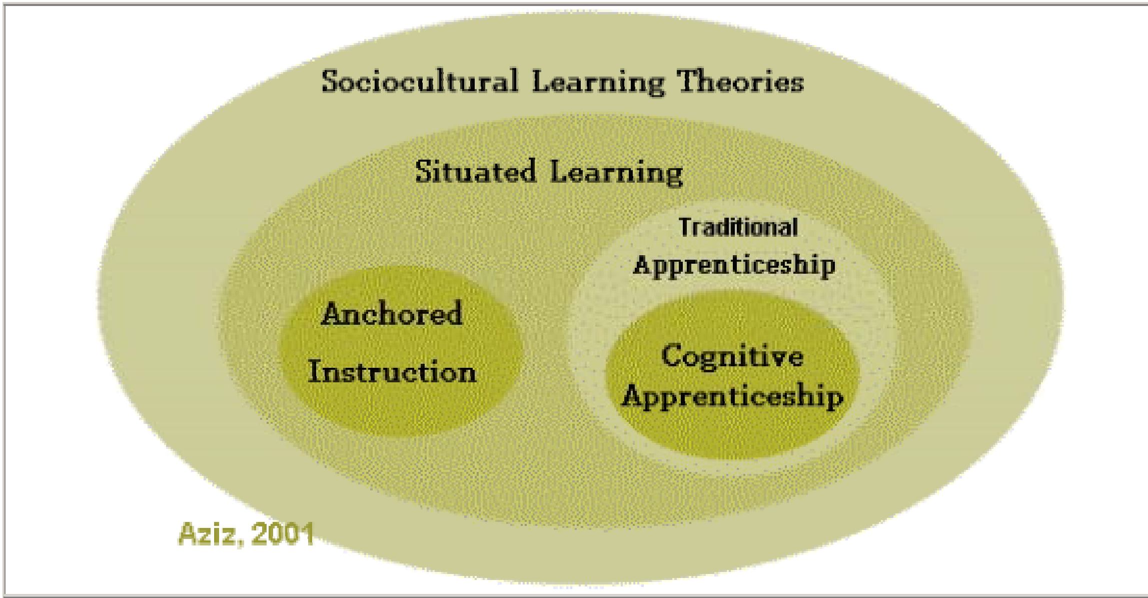

FIGURE 1. The roots and place of cognitive apprenticeship in educational literature

Socio-cultural Theory of Learning

Sociocultural describes a variety of theoretical positions that attribute an inherently social character to knowledge and learning. Sociocultural theory (also called sociohistoricism) is a complex, dynamic explanation of cognitive development that is now recognized as a practical theory of learning and teaching in educational and information technologies literature. Sociocultural theory argues that knowledge acquisition is essentially and inescapably a socio-historical-cultural process (Driscoll, 2000). Perhaps the most influential theorist emphasizing social interaction as a determinant of the qualities of the mind is Lev Vygotsky (1978, 1987). Vygotsky maintained that human development and learning (e.g., social characteristics, communication styles, personality, cognitive ability, linguistic styles, and academic background) originate and develop out of social and cultural interaction. As knowledge is situated in culture and within a historical context, meaning is the result of participation in social activities. Although physical objects can be used as tools for learning, Vygotsky argued that social tools, such as language and other sign systems, play the most central role in development and learning. Children are socialized into learning and using the appropriate cognitive and communicative tools that have been passed down from generation to generation (Greeno,Collins, & Resnick, 1996). This means that children learn cognitive (thinking) and linguistic skills from more capable caretakers, peers, and teachers who assist and regulate the child's cognitive and linguistic performance. Through such socialization, children learn the accumulated ways of thinking and doing that are relevant in their culture/s. And through guided intervention, higher mental functions that are part of the social and cultural heritage of the learner will shift from the socially regulated to the self-regulated. Certainly, Vygotsky's most widely applied idea is that of a *zone of proximal development* (ZPD).

Vygotsky's Zone of Proximal Development (ZPD)

According to Vygotsky, human development and learning originate and develop out of social and cultural interaction within what he calls the "zone of proximal development" (Vygotsky,1987). Vygotsky distinguished between the *actual* development of the child and the *potential* development of the child. Actual development is determined by what a child can do unaided by an adult or teacher. Potential development, in contrast, is what a child can do " throufg problem solving under adult guidance or in collboration with more capable peers" (Vygotsky, 1978, p.86). This area of potential development Vygotsky termed the the zone of proximal development. Therefore, the zone of proximal development is the gap or area between actual and potential development. That is, between what a child can do unaided by a more knowledgeable person (adult, parent, teacher, peer) and what she or he can do under the guidance of a a more knowledgeable person. It is within this area that cognitive apprenticeship (and other means of assistance and instruction) take place (Collins, Brown, & Holum, 1991). On this basis, Vygotsky proposes that an essential feature of learning is the creation of zones of proximal development. Figure 2 conceptualizes the ZPD as related to cognitive apprenticeship.

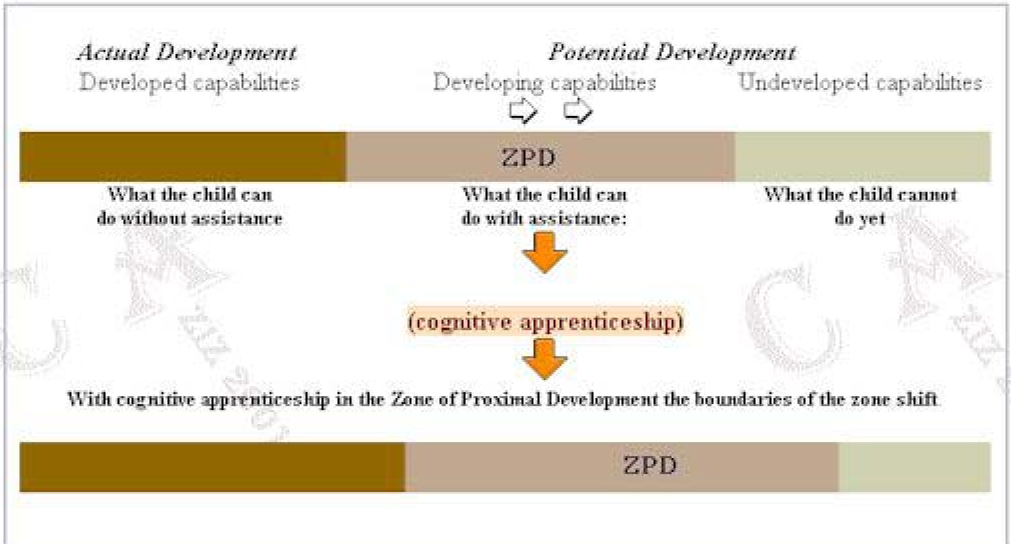

FIGURE 2. A conceptualization of zone of proximal development and the role of cognitive apprenticeship

Situated Cognition

Drawing on sociocultural theory, situated cognition (or learning) refers to the idea that cognitive processes are situated (located) in physical and social contexts (Greeno et al., 1996). Positioned as an alternative to information-processing theory, situated cognition views thinking as embedded in context and draws upon social, cultural, and material resources that never exactly the same for any two individuals or in any two context. Thus, cognitive processes involve relations between a person and a situation; they do not reside solely in one's mind. That is why situated learning is often described as "enculturation," or adopting the norms, behaviors, skills, beliefs, language, and attitudes of a particular community (Lave, & Wenger, 1991; Rogoff, 1990). Although the dominant movement during the 1990s has been to a situated perspective of cognition, there has been considerable variation in the understanding just what is meant by situated cognition or situativity theory. Wilson and Myers (2000) assert that the terms situated cognition, situated action, or situativity enjoy no consensus among researchers. Hence, what might be called the "situtionest" movement is not a unitary viewpoint. It covers an array of related perspectives or sub-theories. Here I summarize what I believe the five key dimensions of this movement:

1. Context. Knowledge is anchored and indexed by the context in which the learning activity occurs. (Brown et al., 1989). If we want to understand what a person does, we first have to know in which context that person is. The knowledge content is determined by it's real world counterpart and context. If knowledge is decontexturalized, then it becomes inert; the student learns a new concept but is unable to utilize it since there is no realistic context for its use. Thus, learning and knowing are perceived as context-specific social processes (Rogoff, 1990). Meaning emerges from the relationship between content and its context. Contexts gives meaning to content. A new emerging and one of the hot topics in education literature today is the notion of contextual teaching and learning. A very recent book by Elaine Johnson (2002) titled *Contextual Teaching and Learning: What It Is and why It's Here to Stay,* is devoted to this single notion. Related to the concept of context is the notion of *authenticity*.

2. Authenticity. The Authenticity principle refers to the quality of having correspondence to the real world. Authenticity in education also means coherent, natural, meaningful, and purposeful activities that represent the ordinary practices (Carraher & Schliemann, 2000). Situated cognitivists argue that everyday learning (i.e., learning that occurs as a function of being in the world) always takes place within a socially and culturally informed context; it this context, this situation, that shapes both knower and knowledge. Authenticity is the central unit of analysis for a growing body of studies called *everyday cognition (or reasoning)* in psychology during the1980s and 1990s (Driscoll, 2000). The aim of everyday cognition is "to examine the ways in which thinking occurs in the real world (e.g., home, street, and workplace) and to bring into discussion questions about the educational relevance of everyday experiences and of learning that takes place outside of classrooms" (Carraher & Schliemann, 2000, p. 174). Everyday cognition not only stresses the problem-solving nature of everyday cognitive activity but also stresses the extent to which it is shaped by social interaction with others (Rogoff & Lave, 1988).

3. Activity & Participation. Knowledge construction results from activity (Jonassen, 1999). Therefore, knowledge is embedded in activity. We cannot separate our knowledge of things from our experiences with them. Central to the literature on situated cognition are notions advanced by *activity theory*. Activity theory, attributed to Leontiev (1978 & 1981), claims that conscious learning and activity (performance) are completely interactive and interdependent (Rogoff, 1990). Accordingly, we cannot act without thinking or think without acting. Participation, on the other hand, describes the interchange of ideas, attempts at problem solving, and active engagement of learners with each other and with the materials of instruction. It is the process of interaction with others that produces and establishes meaning systems among learners. From a situated cognition perspective, learning occurs in a social setting through dialogue with others in the community (Lave 1988). Learning becomes a process of reflecting, interpreting, and negotiating meaning among the participants of a community. Learning is the sharing of the narratives produced by a group of learners.

4. Community of practice. Barab and Duffy (2000) discussed another form of situativity that is paralleled to the usual psychological approach. That is the "anthropological" approach, reflected most heavily in the work of Lave and her colleagues (e.g., Lave & Wenger 1991). Rather than focus on the situatedness of meaning or content, the anthropological perspective focuses on communities and what it means to learn as a function of being a part of a community. This shift in the unit of analysis from the individual's context to the community context leads to a shift in focus from the learning of skills or developing understandings to one in which "developing an identity as a member of a community and becoming knowledgeably skillful are part of the same process, with the former motivating, shaping, and giving meaning to the latter, which it subsumes" (Lave, 1993, p. 65). The goal of learning, therefore, is to engage learners in *legitimate peripheral participation* in communities of practice (Lave and Wenger 1991). Through community, learners interpret, reflect, and form meaning. Community provides the setting for the social interaction needed to engage in dialogue with others to see various and diverse perspectives on any issue. Community is the joining of practice with analysis and reflection to share the tacit understandings and to create shared knowledge from the experiences among participants in a learning opportunity (Wenger 1998).

5. Shared or distributed cognition. A fifth, and to some researchers, more important, dimension of the move to situate cognition has been its exploration of "shared" or "distributed" cognition. Brown et al. (1989) argued that a theory of cognitive situations is beginning to emerge that takes the distributed nature of cognition as a starting point. In fact, the theory of distributed cognition (advanced by Hutchins, 1995; Pea, 1993 and others) argues that cognition is not to be found within the head only; rather cognition is distributed in the world among individuals, the tools, artifacts, and books that they use, and the communities and practices in which they participate (Greeno et al., 1999). To say that cognition is socially shared is to say that it is distributed (among artifacts as well as people) and that it is situated in time and space. Because it is distributed, and its assembly requires the active engagement of those involved, it is to some extent constructed (Brown & Cole, 2000). The idea that cognition is distributed has recently attracted a lot of interest mostly due to theoretical developments (sociocultural psychology) and technological advances (Internet and computer mediated communication).

Cognitive apprenticeship practices, along with anchored instruction (CTGV, 1990 & 1993) and its associated model of *Jasper* Series (CTGV, 1992), computer-supported collaborative learning CSCL (Bowers & Benford, 1991), Computer Supported Intentional Learning Environment CSILE (Scardamalia, et al., 1989 & 1994), learning communities (Barab & Duffy 2000), cognitive flexibility hypertext (Spiro, Feltovich, Jacobson & Coulson, 1992), goal-based scenarios (Schank, 1994), case-based learning (Kolodner, 1997), and contextual teaching and learning (Johnson, 2002), are different instructional design models derived from the situated learning theory.

From Traditional To Cognitive Apprenticeship

Over the centuries, apprenticeships have proved to be an effective form of education. By working alongside a master and perhaps other apprentices, young people have learned many skills, trades, and crafts. The apprenticeship system often involves a group of novices, students, who serve as resources for each other in exploring the new domain and aiding and challenging one another. The expert or teacher is relatively more skilled than the novices, with a broader vision of the important features of the activity. A slightly different spin on apprenticeship, the notion of cognitive apprenticeship, has been presented by Allan Collins and his colleagues as a way of replicating the critical elements of actual apprenticeship for the learner confined to the classroom. Thus, cognitive apprenticeship is the deployment of apprenticeship in the process of learning (Brown, Collins, & Duguid, 1989). Differences between traditional apprenticeship and cognitive apprenticeship have been defined by Collins et al. (1989) as summarized in Table 1.

Traditional Apprenticeship	Cognitive Apprenticeship
Simple tasks	Complex tasks/problem-based
Physical skills and processes	Cognitive and metacognitive processes

One-on-one learning in the workplace	Learning with several students set in the classroom and laboratory
Tasks performed by observation	Tasks and processes performed by reasoning
Learning by doing physical tasks	Learning by externalizing thought processes in diagnosing problems
Learning from modeling, coaching, and fading of performance	Learning from modeling, coaching, Scaffolding, articulation, reflection, and exploration of ideas
Job determined by tasks	Learning determined by outcomes

TABLE 1. Differences between traditional apprenticeship and cognitive apprenticeship

COGNITIVE APPRENTICESHIP AND INSTRUCTIONAL DESIGN

Designing Ideal Learning Environments

Since the early1990s, educators have proposed a number of conceptual frameworks to guide the design and use of learning environments. One of these frameworks was the cognitive apprenticeship model proposed by Collins and colleagues (1989 & 1991). As we have already explained, the cognitive apprenticeship model represents a fusion of the cognition theories of sociocutural, zone of proximal development, and elements of traditional apprenticeship and situativity theory. To summarize:

- Cognitive apprenticeship is situated within the social constructivist paradigm;
- Cognitive apprenticeship is a representative of Vygotskian "zones of proximal development" in which student tasks are slightly more difficult than students can manage independently, requiring the aid of their peers and instructor to succeed;
- Cognitive apprenticeship reflects situated cognition theory;
- Cognitive apprenticeship draws its inspiration from traditional apprenticeship and creates a meaningful social context in which learners are given many opportunities to observe and learn expert practices;

- Cognitive apprenticeship *enculturates* learners into authentic practices through activities and social interaction, they are able to develop the cognitive skills of practitioners.

Collins and colleagues (1989 & 1991) provide the following framework for an ideal cognitive apprenticeship learning environment. They argued that effective learning environments could be characterized through 18 features belonging to four broad dimensions (or building blocks), namely content, methods, sequencing, and sociology of teaching (see Figure 3). Many parts of this model are not new, but together they define an effective learning situation, with very different classrooms and roles for teachers and students.

The remainder of this paper will describe each characteristic of this ideal framework and how they relate to technology.

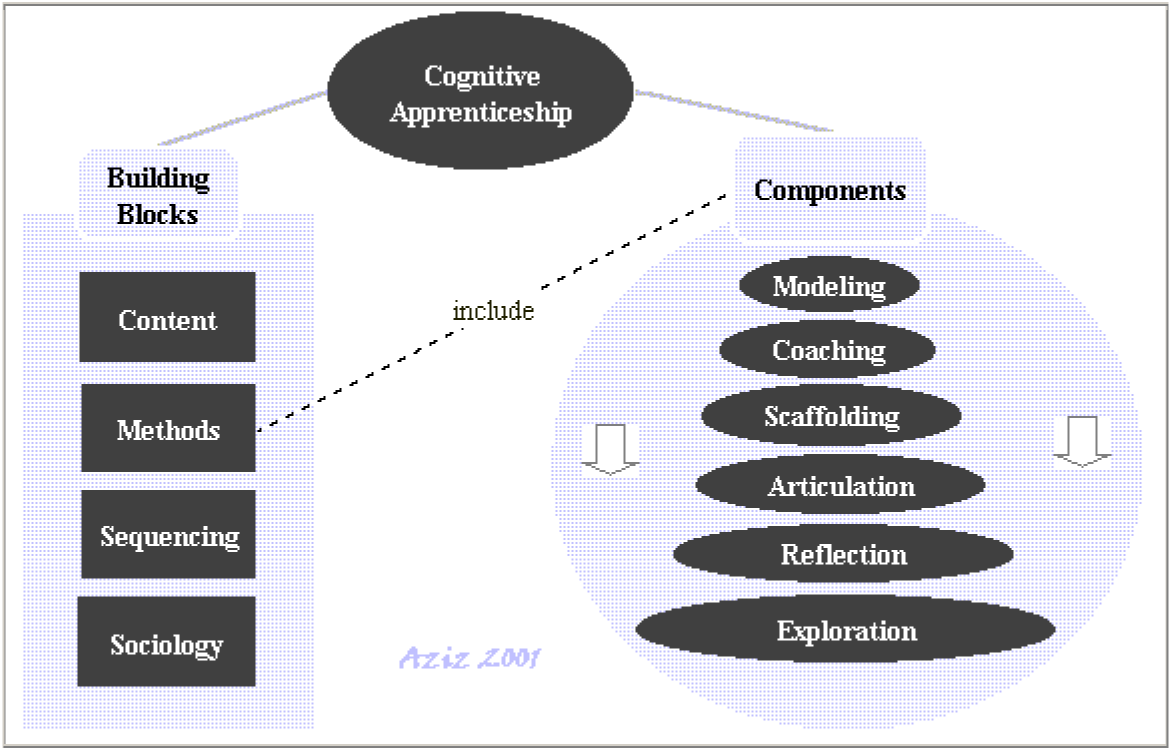

FIGURE 3. Overview of the cognitive apprenticeship model (blocks & components)

Building Blocks of Cognitive Apprenticeship Environments

Collins, Brown, and Newman (1989), Collins, Brown, and Holum (1991), and Collins (1991) identify four aspects (we call it here building blocks) of cognitive apprenticeship learning environment: content, instructional methods, sequencing of instruction, and sociology. The four building blocks along with their 18 features are outlined in Table 2.

CONTENT		*Types of knowledge required for expertise*
1	Domain knowledge	Subject matter, specific concepts, facts, and procedures
2	Heuristic strategies	Generally applicable techniques for accomplishing tasks
3	Control strategies	General approaches for directing one's solutions process
4	Learning strategies	Knowledge about how to learn new concepts, facts, and procedures
METHODS		***Ways to promote the development of expertise***
5	Modeling	Master performs a task so students can observe
6	Coaching	Master observes and facilitates while students perform a task
7	Scaffolding	Master provide supports to help students to perform a task
8	Articulation	Master encourages students to verbalize their knowledge; thinking
9	Reflection	Master enable students to compare their performance with others
10	Exploration	Master invites students to pose and solve their own problems
SEQUENCING		***Ways to ordering learning activities***
11	Increasing complexity	Meaningful tasks gradually increasing in difficulty
12	Increasing diversity	Practice in a variety of situations to emphasize broad application
13	Global before local	Conceptualizing the whole task before executing the parts
SOCIOLOGY		***Social characteristics of learning environments***

14	Situated learning	Students learn in the context of working on realistic tasks
15	Culture of expert practice	Communication about different ways to accomplish meaningful tasks
16	Intrinsic motivation	Students set personal goals to seek skills and solutions
17	Exploiting cooperation	Students work together to accomplish their goals
18	Exploiting competition	Constructive and productive competition blended with cooperation

Table 2. The 18 features for designing cognitive apprenticeship environments

Instructional Methods of Cognitive Apprenticeship Environments

The cognitive apprenticeship approach, as formulated by Collins *et al* (1989 & 1991), consists of six teaching methods: *modelin*g, *coachin*g, *scaffoldin*g, *articulatio*n, *reflectio*n, and *exploratio*n. The six methods, in turn, break down into three groups. The first group -modeling, coaching, and scaffolding- represents the core and is designed to help students acquire an integrated set of cognitive skills through observation and supported practice. The second group -articulation and reflection- is designed to focus students' observations of expert problem solving and to gain control of their own problem solving strategies and metacognitive skills. The final group -exploration- is intended to encourage learner autonomy, problem formulation by the self, and transfer. Table 3 provides a summary of roles of cognitive masters and students and the target outcomes for these six teaching methods.

In ***Modeling (and Explaining),*** the cognitive master models processes to show "how the process unfolds" or how the mentor/peers function in certain situations. In other words, an expert performs a task so that students can observe his actions and build a conceptual model of the processes required for task accomplishment. The provision of a conceptual model contributes significantly to success in teaching complex skills without resorting to lengthy practice of isolated subskills. In cognitive domains, this necessitates the externalization of internal cognitive processes. Tacit processes are brought into the open so that students can observe, enact, and practice the requisite skills. Explaining involves giving “reasons why it happens that way” or providing rationale for processes. Learners see the process for problem-solving and see different ways to trouble-shoot. They also observe what is happening and why things happen the way they do.

In ***Coaching,*** the cognitive master provides assistance to learners as needed by providing individual attention on difficulties the learners are having, providing help at “critical times” or when the learners most need it, providing requested assistance as needed and withdrawing unneeded help, and asking relevant questions to stimulate thought and provide a different point-of-view of situations. Here students are engaged in problem-solving activities that require them to appropriately apply and actively integrate subskills and conceptual knowledge. In this way, conceptual and factual knowledge are exemplified and situated in their contexts of use, thereby grounding the knowledge in experience and making learning meaningful. Consequently, this approach helps to avoid learning outcomes where knowledge remains bound to surface features of problems as they appear in textbooks. The expert coaches students by providing hints, feedback, and reminders to assist students to perform closer to his level of accomplishment. As they coach, they sometimes offer additional modeling or explanation.

In ***scaffolding (and fading),*** the cognitive master assists students to manage a more complex task performance. If necessary, the cognitive master completes those parts of the task that students have not yet mastered. This method may entail students engaging in legitimate peripheral participation (Lave and Wenger, 1991). That is, students participate in the practice of an expert, but only to the extent that they can handle and with the amount of responsibility that they are capable of assuming. Scaffolding is coupled with *fading*, the gradual removal of the cognitive master’s support as students learn to manage more of the task on their own. The interplay between observation, scaffolding, and increasingly independent practice aids students in developing the metacognitive skills of self-monitoring and self-correction and in achieving integrated skills and knowledge characteristic of expertise. Thus, modeling and coaching support students’ efforts to "grow into" domain competence while scaffolding and fading support students’ efforts to "grow out of" dependence on the expert.

In ***articulation,*** learners are required to “explain and think about what they are doing” by making their knowledge explicit. Therefore, they can see other applications for their knowledge, and test their understanding of knowledge. The role of the cognitive master here is to encourage students to explicate their knowledge, reasoning, and problem solving strategies. Such activities provide the impetus for students to engage in the refinement and reorganization of knowledge. Such tasks require students to participate in generating knowledge and evaluating the outcomes of knowledge-building activities as part of collaborative learning activities.

In ***reflection,*** learners reflect on work they have already performed and analyze or deconstruct it. Through this process, they can increase their "awareness of their own knowledge" (also called metacognition) and be able to compare what they know with what others know. Here, the cognitive master role is to provoke students to compare their problem solving processes with the master's work, with that of other students, and with an internal cognitive model of the relevant expertise. Such comparisons aid students in diagnosing their difficulties and in incrementally adjusting their performance until they achieve competence. Reflection is facilitated by the provision of abstracted replay that contrasts students' own performance with that of the expert (Collins and Brown, 1988). Shared articulation and reflection usually magnifies the benefits of these processes.

In ***exploration,*** learners try out different hypotheses, methods and strategies by exploring their project and work environment. Through exploration they can learn how to set achievable goals, form and test hypotheses, and make independent discoveries. Here, the cognitive master role is to encourage students to be independent learners; identify personal interests; and pursue personal goals. In fact, forcing students to engage in exploration teaches them how to frame interesting questions and to identify difficult problems on their own. Giving students an interesting assignment with only generally formulated goals gives students the latitude to explore and thus extend their understanding of a subject. Exploration can also help students gain confidence in their ability to learn on their own.

Table 3 provides a synopsis of the roles of cognitive masters and learners as well as the target skills as related to the six methods of cognitive apprenticeship.

Component	**Cognitive Masters'* Role**	**Students' Role**	**Target**
Modeling	• Show	• Observe	**Receptive**

	students how to do tasks • Build a conceptual model of the processes • Explain reasons why things happen that way • Provide rationale for processes	• Watch/listen • conceptualize	
Coaching	• Observe students attempt a task • Provide assistance as needed • Offer hints, feedback, and guidance	• Perform a task • Engage in problem- solving activities	**meaningful learning** (Declarative & Heuristic Knowledge)
Scaffolding "fading"	• Offer little support, guidance, and reminders • Assists students to manage complex task performance • If necessary, complete those parts	• Perform a more complex task • Work independently • Engage in legitimate peripheral.participation	

	of the task that students have not yet mastered • Gradual removal of support (fading)		
Articulation	• Require their students to explain what they are doing • Encourage students to explicate their knowledge, reasoning, and problem solving strategies	• Explain their knowledge • Discuss their strategies • Thinking aloud	**Metacognition**
Reflection	• Encourage students to reflect on their tasks • Provoke students to compare their work with masters', other students, and with an internal cognitive model of the relevant	• Reflect on work they have already performed and analyze or deconstruct it • Compare what they know with what others know • Contrast their works with that of others	

	expertise		
Exploration	• Encourage students to solve new, but similar, tasks • Push students to be independent learners • Force students to engage in exploration	• Solve new, but similar, tasks • Frame and explore interesting questions • Make independent discoveries • Identify personal interests and pursue personal goals	**Application/ Transfer**

*Cognitive masters include experts, teachers, computer programs, software, hypermedia, computerized coaching systems etc.

Table 3. A summary of roles of cognitive masters and students and target outcomes for the cognitive apprenticeship six teaching methods.

COGNITIVE APPRENTICESHIP AND EDUCATIONAL TECHNOLOGY

Role of Technology in Cognitive Apprenticeship

Emerging technologies are leading to the development of many new opportunities to guide and enhance learning that were unimagined even a few years ago. Computer-based technologies hold great promise both for increasing access to knowledge and as a means of promoting learning. Within the framework of cognitive apprenticeship, computer-based technologies can be powerful pedagogical tools that enhance and expand the power and flexibility of the resources that can be deployed to support the various component of cognitive apprenticeship discussed earlier. In turn, cognitive apprenticeship approach can serve as solid foundation for the instructional design of computer-based environments whether it is a multimedia, hypermedia, web-based, or any means of technological delivery systems (Casey, 1996).

There are many ways that technology can be used to help meet the challenges of establishing effective cognitive apprenticeship environments:

1. Authenticity and bringing real-world problems into classrooms. One of the central elements of technological environments presumed to authenticate learning is that of simulating the social process learning rely on in their everyday lives (Jonassen, Peck, & Wilson, 1999). This ability is realized especially through virtual reality and hypermedia applications, where the real world can be simulated or brought into the classroom. Moreover, recent prominent technologies for computer such as the Internet, e-mail, and e-learning bring students close to real-world environments and apprenticeship opportunities.

2. Access to expert performance and working scientists. That can be easily done through the use of videos, embedded expert-systems, demonstrations, simulations, Internet connections (Wenger 1998).

3. Providing coaching and scaffolding. Technology also serves the important role of coach by locating the points in the problem-solving process where students are having difficulty and by providing as much coaching as the learner needs to accomplish the task. Scaffolding allows learners to participate in complex cognitive performances, such as scientific visualization and model-based learning, that is more difficult or impossible without technical support (Casey, 1996; Jonassen, Peck, & Wilson, 1999).

4. Making thinking visible. Collins (1991) contends that "computers ... can make the invisible visible ... they can make tacit knowledge explicit ... to the degree that we can develop good process models of expert performance, we can embed these in technology, where they can be observed over and over for different details" (p. 125).

5. Flexibility and interactivity. Technology allows cognitive apprenticeship model to be broken down into processes and sub-processes in ways that books traditionally have been unable to, and even ways in which human mentors cannot. Moreover, in technological environments, modeling, reflection and articulation for example can be laid out in two-or more-dimensional form (i.e., pictures, videos, or computer models) and, thus, students have an added opportunity to reflect on their learning (Herrington & Oliver, 2000; Spiro et al., 1992)

6. Metacognition. Computers also offer students opportunities for metacognition. Hypermedia and multimedia courseware is also inherently able to provide for many other key components of the cognitive apprenticeship model such as articulation, reflection, collaboration, and multiple perspectives (Herrington & Oliver, 2000). Through the medium of interactive computer microworlds, learners acquire hands-on and minds-on experience and, thus, a deeper understanding of subject mater (Jonassen, Peck, & Wilson, 1999).

7. Epistemological pluralism and individual differences. Computers make it possible to provide the sort of individualized training masters provide for apprentices in the traditional model of apprenticeship. Collins et all. (1989) suggest that without the highly individualized elements of teacher modeling, coaching, and scaffolding, apprenticeship is impossible. Appropriately designed computer based cognitive apprenticeship can make a style of learning that was previously severally limited, cost effective and widely available. Additionally, computers can afford students the opportunity to think at their own epistemological desires and learning styles. Turkle and Papert (1991) emphasize the role of computers in supporting epistemological pluralism. The computer, with its graphics, sounds, its text and animation, can provide a port of entry for people whose chief ways of relating to the world are though movement, intuition, visual impression, the power of words and associations.

To recap then, Collins et al. (1989) and Collins (1991) argue that technologies that support cognitive apprenticeship can actually improve the traditional apprenticeship model. Educational technologies can help in overcoming sever limitations associated with the traditional cognitive apprenticeship by creating learning contexts that are authentic (real apprentice-like) and permit a greater number of opportunities for learners' epistemological styles, pace, flexibility, self-correction and learning modification. With appropriate types of technology, students can reflect and articulate their understanding and make their thinking visible.

A large number of researchers have used different types of technology to implement cognitive apprenticeship, and found very good results (e.g., Casey, 1996; Cash, Behrmann, & Stadt, 1997; Chee, 1995; De Bruin, 1995; Duncan, 1996; Jarvela, 1995, 1996; Looi & Tan, 1998. For instance, Casey (1996) examined the use of cognitive apprenticeships as a framework for multimedia instructional design to help address the needs of a distributed learning environment. Findings indicated that the cognitive apprenticeship approach provides a prescriptive method for analyzing and sequencing content and developing suitable strategies for learning, a tool for incorporating communities of practice in multimedia solutions, and a framework for building and reinforcing cognitive understanding. In a qualitative study, Jarvela (1995) analyzed the qualitative features of teacher-student interaction in a technologically rich learning environment based on a cognitive apprenticeship model. He concluded that the technologically rich learning environment facilitated learning in social interaction based on cognitive apprenticeship.

Technology-Based Cognitive Apprenticeship Projects

Examples of available technology-based cognitive apprenticeship environments include:

- **SMALLTALKER:** A cognitive apprenticeship Macintosh-based multimedia environment for learning Smalltalk programming (See Chee,1994 for details).
- **WORDMATH:** Software packages designed based on applying teaching methods from the cognitive apprenticeship approach (See Looi, & Tan, 1998 for details).
- **Electronic Emissary Project at the University of Texas at Austin:** It is based at the University of Texas at Austin, in the College of Education. The Emissary is a "matching service" that helps teachers with access to the Internet locate other Internet account-holders who are experts in different disciplines, for purposes of setting up curriculum-based, electronic exchanges among the teachers, their students, and the experts.
- **CoVis (Learning through Collaborative Visualization):** CoVis is an integrated learning environment of visualization tools and communication tools. The software systems of the CoVis environment include an asynchronous networking system, the Collaboratory Notebook.
- **Virtual Exploratorium:** The Virtual Exploratorium is a 3-D computer learning environment that provides discovery-based learning in the field of geosciences.
- **Teaching Teleapprenticeship Project (TTa):** TTa is an example that based on the theory of cognitive apprenticeship, developed by The College of Education at the University of Illinois (See Thurston, Secaras, & Levin, 1996; Levin, & Waugh, 1998 for details).

Applying Selected Technologies To Methods of Cognitive Apprenticeship

Finally, the following table includes a number of various technologies that can be applied to the six instructional methods of cognitive apprenticeship suggested by the writer.

Components	Example of Technology Applications
Modeling	• Expert communicates with student via digitized video • Expert shows how things work and how things are done using animations • Watching and observing built-in movies and voice narration • Expert reifies cause-and-effect relationships; presents goals before actions • Online expert examples of case solutions • Online problem solving samples • web-cams • Simulation/Virtual reality software
Coaching	• Students work on programming/ multimedia/ hypermedia/ online tasks of increasing difficulty • Highly situated feedback is given in response to student errors and actions • Expert helps by e-mail and similar means • Computer conferencing with experts and peers • Online problem solving strategies • web-cams
Scaffolding "fading"	• Student-initiated help system available through specific button • Students can replay movies to review instructional materials • Help system provides a "Show Me" button as a last recourse • Feedback dialogs are generalized when errors of the same type are made • Recourse to more detailed information remains available • Online testing • Online diagnosis • Online instructions

	• Online coaching
Articulation	• System poses a conceptual questions to articulate the answers to the questions either to themselves or to a friend • Deeper conceptual significance posed to students • Online questioning and answering • Online discussion via e-mail, listservs, chat rooms, and forums • Hypermedia representations of problem solving solutions • Constructing Microworlds • Multimedia authoring tools • Web page design and construction
Reflection	• Play Movie button plays a digitized movie of an expert expressing his view on the reflection question posed • Multiple perspectives on shared workspace/issue/problem/artifact • Comparison of one's own solutions with expert and/or peer solutions • Using evaluative judgment on web-based resources • Book-marking feature saves and retrieves entries for future reference • Developing computer-based portfolios • Online discussion via e-mail, listservs, chat rooms, and forums
Exploration	• Explore button so students can further explore the system/task on their own and pursue their own goals • Online exploration strategies • Multiple representations of a problem/Hypermedia representations • Constant availability of tools and instructional library • Multiple search options including browse • Using available technologies to represent data in new ways • "Go On-line" menu links users to Web-based resources

Table 4. Suggested technology tools to be applied to the six instructional methods of cognitive apprenticeship.

CONCLUSION

With the rise of the situated cognition paradigm in cognitive science, cognitive apprenticeship has become increasingly prominent as a model of instruction. It is felt that the notion of apprenticeship as a model for cognitive development is ideal as it focuses on the active role of learner organizing development, the active support and use of people in social interaction, arrangements of tasks and activities, and the ordered nature of the institutional contexts, technologies, and goals of cognitive activities. Shared learning is central to the process of learning in apprenticeship. The importance of routine activities, supportive structuring of students efforts, and transfer of responsibility for handling skills to students is central.

Like any other instructional models, cognitive apprenticeship affords the following, and certainly other, opportunities and challenges.

Cognitive apprenticeship practices are beneficial because they:

- Represent a reaction to the separation of the school, or other types of educational institutions, from its surrounding society and community;
- Encourage authentic activity and assessment and, thus, greater levels of retention and transfer;
- Motivate and engage learners in higher order cognitive reasoning/ thinking;
- Make thinking visible and enhance metacognition skills;
- Facilitate learning-through-guided experience so students think like technicians, scientists and mathematicians.

Teachers using a cognitive apprenticeship approach in their classrooms might encounter challenges that could result in the failure of the practice. These challenges include:

- Cognitive apprenticeship may require different roles for teachers : from a knowledge transmitter to a coach or facilitator of students' understanding;
- Cognitive apprenticeship may provoke higher levels of student anxiety and frustration;
- Cognitive apprenticeship may require more time on task;
- Cognitive apprenticeship may require additional or more sophisticated resources;

- Cognitive apprenticeship may require a fundamental change in test traditions: focus on the individual's cognitive progress and transfer of knowledge (testing the cognitive progress).

The cognitive apprenticeship approach has been applied in a good deal of conceptual, quantitative, and qualitative studies in various settings an domains including technology integration. Cognitive apprenticeship has proved successful in promoting student's higher order thinking skills as well as in shaping the social interactions between teachers and students to goal-oriented problem solving.

This model can be further enhanced when supported by appropriate technologies. Technology enables us to realize cognitive apprenticeship learning environments that were either not possible or not cost effective before.

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