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AUTHOR Wilson, Brent; Cole, Peggy

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ABSTRACT

This discussion of the relationship between two related disciplines--cognitive psychology and instructional design (ID)--characterizes instructional design as a more applied discipline, which concerns itself more with prescriptions and models for designing instruction, while instructional psychologists conduct empirical research on learning and instructional processes. It is posited that a problem-solving orientation to education is needed if schools are to achieve substantial learning outcomes, and the concept of cognitive apprenticeships, which emphasize returning instruction to settings where worthwhile problems can be worked with and solved, is proposed as a possible solution to this problem. A brief review of ID models focuses on instructional-design theory, component display theory, and elaboration theory, pointing out that some of the teaching models proposed by cognitive researchers bear strong resemblance to traditional ID models. The design elements of the cognitive apprenticeship model are then reviewed and related to traditional ID concepts. Examples of cognitive apprenticeships are given for teaching writing, reading, math, and weather forecasting. It is concluded that, even though instructional-design theorists may chafe at the continuing need to revise their theories in light of advances in psychological theory, it is good for both fields for the dialogue to continue. (46 references) (BBM)

Title:

Cognitive Apprenticeships: An Instructional Design Review

Authors:

Brent Wilson
Peggy Cole

Cognitive Apprenticeships: An Instructional Design Review

Brent G. Wilson and Peggy Cole
University of Colorado at Denver

The field of instructional design (ID) emerged more than 30 years ago as psychologists and educators searched for effective means of planning and producing instructional systems (Reiser, 1987; Merrill, Kowallis, & Wilson, 1981). Since that time, instructional designers have became more clearly differentiated from instructional psychologists working within a cognitivist tradition (Resnick, 1981; Glaser, 1982; Glaser & Bassok, 1989). ID theorists tend to concern themselves with prescriptions and models for designing instruction while instructional psychologists conduct empirical research on learning and instructional processes.

Of course, the distinction between designers and psychologists is never clear-cut. Over the years, many psychologists have put considerable energy into the design and implementation of experimental instructional programs. Because the two fields support different literature and theory bases, communication between the two fields is often strained. Thus much design work of cognitive psychologists has gone relatively unnoticed by instructional design theorists.

Collins, Brown, and colleagues (e.g., Collins, Brown, & Newman, 1989) have developed an instructional model derived from an analysis of the way apprentices work under experts in traditional societies and from the way people seem to learn in everyday informal environments (Rogoff & Lave, 1984); they have called their model *cognitive apprenticeships*, and have identified a list of features found in "ideal" learning environments. Instructional strategies, according to the Collins-Brown model, would include modeling, coaching, scaffolding and fading, reflection, and exploration. Additional strategies are offered for representing content, for sequencing, and for maximizing benefits from social interaction.

Of course, many of Collins' recommended strategies resemble strategies found in the instructional-design literature (e.g., Reigeluth, 1983). Clearly both fields could benefit from improved communication concerning research findings and lessons learned from practical tryout. With that goal in mind, the purpose of this paper is to analyze the Collins-Brown cognitive apprenticeship model from an instructional-design point of view. In addition to general strategies and recommended components, several teaching systems employing cognitive apprenticeship ideals are described. The resultant review should prove valuable in two ways: (1) cognitive psychologists should be able to make a better correspondence between their models and current ID theory, hopefully seeing areas needing improvement, and (2) instructional-design theorists also should be able to see correspondences and differences, which may lead to revision or expansion of *their* current models.

The Need for Cognitive Apprenticeships

The cognitive apprenticeship model rests on a somewhat romantic conception of the "ideal" apprenticeship into a complex domain (Brown, Collins, & Duguid, 1989). In contrast to the classroom context, which tends to remove knowledge from its sphere of use, Collins et al. recommend returning instruction to settings where worthwhile problems can be worked with and solved. The need for a problem-solving orientation to education is apparent from the difficulty schools are having in achieving substantial learning outcomes (Resnick, 1989).

Another way to think about the concept of apprenticeship is Gott's (1988) notion of the "lost apprenticeship," a growing problem in industrial and military settings. She noted the effects of the increased complexity and automation of production systems. First, the need is growing for high levels of expertise in supervising and using automated work systems; correspondingly, the need for entry levels of expertise is declining. Workers on the job are more and more expected to be flexible problem solvers; human intervention is often most needed at points of breakdown or malfunction. At these points, the *expert* is called in. Experts, however narrow the domain, do more than apply canned job aids or troubleshooting algorithms; rather, they internalize considerable knowledge which they can use to solve flexibly problems in real time.

Gott's second observation relates to training opportunities. Now, at a time when more problem-solving expertise is needed due to the complexity of systems, fewer on-the-job training opportunities exist for entry-level workers. There is often little or no chance for beginning workers to acclimatize themselves to the job, and workers very quickly are expected to perform like seasoned professionals. True apprenticeship experiences are becoming relatively rare. Gott calls this dilemma—more complex job requirements with less time on the job to learn—*the "lost" apprenticeship*, and argues for the critical need for cognitive apprenticeships and simulation-type training to help workers develop greater problem-solving expertise.

A Brief Review of ID Models

Current instructional-design models are based on Robert Gagne's *conditions-of-learning* paradigm (Gagne, 1985), which in its time was a significant departure from the Skinnerian operant conditioning paradigm dominant among American psychologists. The conditions-of-learning paradigm posits that a graded hierarchy of learning outcomes exists, and for each desired outcome, a set of conditions exists that leads to learning. Instructional design is a matter of being clear about intended learning outcomes, then matching up appropriate instructional strategies. The designer writes behaviorally specific learning objectives, classifies those objectives according to a taxonomy of learning types, then arranges the instructional conditions to fit the current instructional prescriptions. In this way, designers can design instruction to successfully teach a rule, a psychomotor skill, an attitude, or piece of verbal information.

A related idea within the conditions-of-learning paradigm claims that sequencing of instruction should be based on a hierarchical progression from simple to complex learning outcomes. R. Gagne developed a technique of learning hierarchies for analyzing skills: A skill is rationally decomposed into parts and subparts, then instruction is ordered from simple subskills to the complete skill. Elaboration theory uses content structure (concept, procedure, or principle) as the basis for organizing and sequencing instruction (Reigeluth, Merrill, Wilson, & Spiller, 1980). Both depend on task analysis to break down the goals of instruction, then on a method of sequencing proceeding from simple to gradually more complex and complete tasks.

These instructional-design models appear to work with well-defined content domains; their most extensive use has been in military settings. There are a couple of potential problems, however, that need to be addressed. First, sequencing of instruction based on the logical structure of content tends to neglect the existing knowledge base of individual learners. ID models often assume new content can be added incrementally to learners' prior knowledge bases without complication. As a simple example, imagine a concept "kinds" hierarchy of animals, vertebrates, mammals, dogs, collies, etc. Following elaboration theory's method of sequencing concept hierarchies,*dog*, being lower in the hierarchy, is considered a more detailed concept than *mammal*; hence, *dog* should not be taught until the concept of *mammal* has been presented. This prescription, of course, fails to take into account children's existing knowledge structure that includes *dog* at a young age but not *mammal*. A more natural sequencing method would start with *dog* and proceed to the unfamiliar technical concepts of *mammals, vertebrates,* etc.

Another problem with current models is their relative neglect of the job of integrating different content elements in learners' minds. As described above, current models break down content into different types of learning outcomes, and prescribe different learning conditions for each type. This analytic approach builds in a bias toward teaching disconnected, isolated content elements out of their naturally occurring contexts. Because rules or skills are often taught separately from facts or verbal information, their interrelatedness tends to be de-emphasized. This is unfortunate, because rules are best taught in meaning-rich environments, and verbal information is best taught in meaningful contexts that include action and problem-solving performance. In fact, different kinds of outcomes seem to depend on each other for optimal learning environments. Teaching one kind of content in exclusion of other kinds creates problems for both learner and teacher. Elaboration theory addresses the problem by recommending periodic synthesizers and summarizers, but its sequencing strategy centers around one kind of learning outcome (concept, procedure, or principle) for an entire course. Thinking of content structure only in terms of concept hierarchies, procedures, or causal models is overly restrictive in light of cognitive research suggesting the importance of other kinds of knowledge structure (Strike & Posner, *in press*).

Some of the teaching models being offered by cognitive researchers bear strong resemblance to traditional ID models. Larkin and Chabay (1989), for example, offer design guidelines for the teaching of science in the schools (pp. 160–163):

1. Develop a detailed description of the processes the learner needs to acquire.
2. Systematically address all knowledge included in the description of process.
3. Let most instruction occur through active work on tasks.
4. Give feedback on specific tasks as soon as possible after an error is made.
5. Once is not enough. Let students encounter each knowledge unit several times.
6. Limit demands on students' attention.

By any standard, these design guidelines are very close to the prescriptions found in component display theory, elaboration theory, and Gagne's instructional-design theory. The strong correspondence can be seen as good news for instructional-design theories: Current cognitive researchers seem to agree on some fundamentals of design that also form the backbone of ID models.

On the other hand, some teaching models recently developed and tested emphasize design elements that traditional ID models historically have under-emphasized. The cognitive apprenticeship model includes some well-worn design elements—such as modeling and fading—and others that are relatively neglected by ID models—such as situated learning, exploration, and the role of tacit knowledge.

FEATURES OF COGNITIVE APPRENTICESHIPS

In the section below, the design elements of the cognitive apprenticeship model (based primarily on Collins, 1991) are reviewed and related to traditional ID concepts.

1. ***Content: Teach tacit, heuristic knowledge as well as textbook knowledge*** Collins et al. (1989) refer to four kinds of knowledge that differ somewhat from ID taxonomies:

- Domain knowledge is the conceptual, factual, and procedural knowledge typically found in textbooks and other instructional materials. This knowledge is important, but often is insufficient to enable students to approach and solve problems independently.
- Heuristic strategies are "tricks of the trade" or "rules of thumb" that often help narrow solution paths. Experts usually pick up heuristic knowledge indirectly through repeated problem-solving practice; however, heuristic knowledge can be made explicit and taught directly.
- Control strategies are required for students to monitor and regulate their problem-solving activity. Control strategies have monitoring, diagnostic, and remedial components; this kind of knowledge is often termed *metacognition* in the literature (Paris & Winograd, 1990).
- Learning strategies are strategies for learning ; they may be domain, heuristic, or control strategies, aimed at learning. Inquiry teaching to some extent directly models expert learning strategies (Collins & Stevens, 1983).

Comment

ID taxonomies (Gagne, 1985; Merrill, 1983) pertain primarily to domain or textbook knowledge, although the distinction is not explicit. Gagne's "cognitive strategies" fits the last three strategies listed by Collins et al. Merrill's "find a principle" or "find a procedure" seems closest to those three strategies. Both Gagne and Merrill are least specific about instruction of this type, although they both acknowledge its importance.

2. ***Situated learning: Teach knowledge and skills in contexts that reflect the way the knowledge will be useful in real life.*** Brown, Collins, and Duguid (1989) argue for placing all instruction within "authentic" contexts that mirror real-life problem-solving situations. Collins (1991) is less forceful, moving away from real-life requirements and toward problem-solving situations: for teaching math skills, situated learning could encompass settings "ranging from running a bank or shopping in a grocery store to inventing new theorems or finding new proofs. That is, situated learning can incorporate situations

from everyday life to the most theoretical endeavors" (Collins, 1991, p. 122).

Collins differentiates a situated-learning approach from common school approaches:

> *We teach knowledge in an abstract way in schools now, which leads to strategies, such as depending on the fact that everything in a particular chapter uses a single method, or storing information just long enough to retrieve it for a test. Instead of trying to teach abstract knowledge and how to apply it in contexts (as word problems do), we advocate teaching in multiple contexts and then trying to generate across those contexts. In this way, knowledge becomes both specific and general.* (Collins, 1991, p. 123)

Collins cites several benefits for placing instruction within problem-solving contexts:

- Learners learn to apply their knowledge under appropriate conditions.
- Problem-solving situations foster invention and creativity (see also Perkins, 1990).
- Learners come to see the implications of new knowledge. A most common problem inherent in classroom learning is the question of relevance: "How does this relate to my life and goals?" When knowledge is acquired in the context of solving a meaningful problem, the question of relevance is at least partly answered.
- Knowledge is stored in ways that make it accessible when solving problems. People tend to retrieve knowledge more easily when they return to the setting of its acquisition. Knowledge learned while solving problems gets encoded in a way that can be accessed again in problem-solving situations.

Although not cited by Collins and colleagues, two other cognitive teaching models are relevant to the notion of situated learning. Bransford and colleagues (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990) have developed an approach called "anchored instruction." They take a Sherlock Holmes or Indiana Jones videodisc and develop problem-solving activities around incidents in the video. The instruction is thus grounded in a rich *macro-context* that is meaningful and interesting to the learner. They have pointed out many similarities to situated learning and cognitive apprenticeships (The Cognition and Technology Group at Vanderbilt, 1990). The second related model is Spiro's *cognitive flexibility theory* (Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro & Jehng, 1990) which grew out of studies of medical students learning advanced subject matter. Spiro and colleagues found that for students to avoid oversimplifying complex content, they needed to see multiple analogies across multiple contexts. Spiro and colleagues used a series of "mini-cases" to help students a mental model that was sensitive to the many nuances and subtleties of the content. Both Bransford's anchored instruction and Spiro's cognitive flexibility theory stress the importance of placing problem-solving instruction within meaningful contexts.

Comment

Taken in its extreme form that would require "authentic," real-life contexts for all learning, the notion of situated learning is somewhat vague and unrealistic. Instruction always involves the dual goals of generalization and differentiation (Gagne & Driscoll, 1989). In its more modest form, however, the idea of context-based learning has considerable appeal. Gagne & Merrill (1990) have pointed to the need for better integration of learning goals through problem-solving "transactions." The notion of situated learning, however it is viewed, challenges the conditions-of-learning paradigm that prescribes the breaking down of tasks to be taught out of context.

3. ***Modeling and explaining: Show how a process unfolds and tell reasons why it happens that way.*** Collins (1991) cites two kinds of modeling: (1) modeling of processes observed in the world and (2) modeling expert performance, including covert cognitive processes. Computers can be used to aid in the modeling of these processes. Collins stresses the importance of integrating both the demonstration and the explanation during instruction. Learners need access to explanations as they observe details of the modeled performance. Computers are particularly good at modeling covert processes that otherwise would be difficult to observe, both natural and mental. Collins suggests that truly modeling expert performance, including the false starts, dead ends, and backup strategies, can help learners more quickly adopt the tacit forms of knowledge alluded to above under the *Content*

section. Teachers in this way are seen as "intelligent novices" (Bransford, Goin, Hasselbring, Kinzer, Sherwood, & Williams, 1988). By seeing both process modeling and accompanying explanations, students can develop "conditionalized" knowledge, that is, knowledge about when and where knowledge should be used to solve a variety of problems.

Comment

ID models presently incorporate modeling and demonstration techniques. Tying explanations to modeled performances is a useful idea, similar to Chi and Bassok's (1989) studies of worked-out examples. Again, the emphasis is on making tacit strategies more explicit by directly modeling mental heuristics.

4. ***Coaching: Observe students as they try to complete tasks and provide hints and helps when needed.*** Intelligent tutoring systems sometimes embody sophisticated coaching systems that model the the learner's progress and provide hints and support as practice activities increase in difficulty. Burton and Brown (1982) developed a coach to help learners with "How the West Was Won," a game originally implemented on the PLATO system. Anderson, Boyle, and Reiser (1985) developed coaches for geometry and LISP programming.

   Coaching strategies can be implemented at least partially in traditional school settings. Bransford and Vye (1989) identify several characteristics of effective coaches:
   - Coaches need to monitor learners' performance to prevent their getting too far off base, but leaving enough room to allow for a real sense of exploration and problem solving.
   - Coaches help learners reflect on their performance and compare it to others'.
   - Coaches use problem-solving exercises to assess learners' knowledge states. Misconceptions and buggy strategies can be identified in the context of solving problems; this is particularly true of computer-based learning environments (Larkin & Chabay, 1989).
   - Coaches use problem-solving exercises to create the "teaching moment." Posner, Strike, Hewson, and Gertzog (1982) present a 4-stage model for conceptual change: (1) students become dissatisfied with their misconceptions; (2) they come to a basic understanding of an alternative view; (3) the alternative view must appear plausible; and (4) they see the new view's value in a variety of new situations (see also Strike & Posner, *in press*).

Comment

Coaching probably involves the most "instructional work" (*cf.* Bunderson & Inouye, 1987) of any of the cognitive apprenticeship methods. Short of one-on-one tutoring, coaching is likely to be partial and incomplete. Cooperative learning and small-group learning methods can provide some coaching support for individual performance. And computers can help tremendously in monitoring learner performance and providing real-time helps; yet presently coaching is only fully implemented in resource-intensive intelligent tutoring systems. Much work is being done to model the essentials of coaching functions on computer systems; we continue to need resource-efficient methods for achieving the coaching function.

5. ***Articulation: Have students think about their actions and give reasons*** for their decisions and strategies, thus making their tacit knowledge more explicit. Think-aloud protocols are one example of articulation (Hayes & Flower, 1980; Smith, 1988). Collins (1991) cites the benefits of added insight and the ability to compare knowledge across contexts. As learners' tacit knowledge is brought to light, that knowledge can be recruited to solve other problems.

Comment

John Anderson (1990) has shown that procedural knowledge—the kind that people can gain automaticity in—is initially encoded as declarative or conceptual knowledge, but later fades as the skill becomes proceduralized. Methods for articulating tacit knowledge helps to restore a conscious awareness of those lost strategies, enabling more flexible performance. Traditional ID models suggest practicing problem solving to learn problem solving, but are surprisingly lacking in specific methods to teach learners to think consciously about covert strategies.

6. ***Reflection: Have students look back over their efforts to complete a task and analyze their own performance.*** Reflection is like articulation, except it is

pointed backwards to past tasks. Analyzing past performance efforts can also involve elements of strategic goal-setting and intentional learning (Bereiter & Scardamalia, 1989). Collins and Brown (1988) suggest four kinds or levels of reflection:

- *Imitation* occurs when a batting coach demonstrates a proper swing, contrasting it with your swing;
- *Replay* occurs when the coach videotapes your swing and plays it back, critiquing and comparing it to the swing of an expert;
- *Abstracted replay* might occur by tracing an expert's movement of key body parts such as elbows, wrists, hips, and knees, and comparing those movement to your movements;
- *Spatial reification* would take the tracings of body parts and plot them moving through space.

The latter forms of reflection clearly rely on technologies—video or computer— for instantiation. Collins (1991) uses Anderson et al.'s Geometry Tutor as an example of reflective instruction.

Comment

Articulation and reflection are both strategies to help bring meaning to activities that might otherwise be more "rote" and procedural. Reigeluth's (1983) concern with meaningful learning is indicative of the need; however, much of traditional ID practice tends to devalue the reflective aspects of performance in favor of getting the procedure down right.

7. ***Exploration: Encourage students to try out different strategies and hypotheses and observe their effects.*** Collins (1991) claims that through exploration, students learn how to set achievable goals and to manage the pursuit of those goals. They learn to set and try out hypotheses, and to independently seek knowledge. Real-world exploration is always an attractive option; however, constraints sometimes prohibit extensive time in realistic settings. Simulations are one way to allow exploration; hypertext structures are another.

Comment

As Reigeluth (1983) notes, discovery learning techniques are less efficient than direct instruction techniques. The choice must depend, to some extent, on the goals of instruction: for near transfer tasks (*cf.* Salomon & Perkins, 1988), direct instruction may occasionally be warranted; for far transfer tasks, learners must learn not only the content but also now to solve unforeseen problems using the content; in such cases, instructional strategies allowing exploration and strategic behavior become essential.

Having thus represented a traditional ID mode of thinking about exploration, I am still left unsatisfied. Following a cognitive-apprenticeship way of thinking, there is something intrinsically valuable about situated problem-solving activity that makes learning work better than straight procedural practice. This is an area that needs better articulation among ID theorists.

8. ***Sequence: Present instruction in an ordering of simple to complex, increasing diversity, and global before local skills.***
   - *Increasing complexity*. Collins et al. (1989) point to two methods for helping learners deal with increasing complexity. First, instruction should take steps to control the complexity of assigned tasks. They cite Lave's study of tailoring apprenticeships: apprentices first learn to sew drawers, which have straight lines, few pieces of material, and no special features like zippers or pockets. They progress to more complex garments over a period of time. The second method for controlling complexity is through scaffolding; for example, group or teacher support for individual problem solving.
   - *Increasing diversity* refers to the variety in examples and practice contexts.
   - *Global before local skills* refers to helping learners acquire a mental model of the problem space at very early stages of learning. Even though learners are not engaged in full problem solving, through modeling and helping on parts of the task (scaffolding), they can understand the goals of the activity and the way various strategies relate to the problem's solution. Once they have a clear "conceptual map" of the activity, they can proceed to developing greater skill at specific skills.

Comment

The sequencing suggestions above bear a strong resemblance to those of elaboration theory (Reigeluth & Stein, 1983) and component display theory (Merrill, 1983). The notion of global before local skills is implicit in elaboration theory; simple-to-complex sequencing is the foundation of elaboration theory. The notion of increasing diversity is the near-equivalent to the prescription to use "varied example" and practice activities in concept or rule learning. The cognitive apprenticeship extends these notions beyond rule learning to problem-solving contexts.

EXAMPLES OF COGNITIVE APPRENTICESHIP

In the section below, I briefly review three approaches that Collins et al. (1989) identify as embodying cognitive apprenticeship features.

Procedural Facilitations for Writing

Novice writers typically employ a *knowledge-telling* strategy: they think about their topic, then write their thought down; think again, then write the next thought down, and so on until they have exhausted their thoughts about the topic. This strategy, of course, is in conflict with a more constructive, planning approach in which writing pieces are composed in a more coherent, intentional way. To encourage students to adopt more sophisticated writing strategies, Scardamalia and Bereiter (1985) have developed a set of writing prompts called *Procedural Facilitations*, that are designed to reduce working-memory demands and provide a structure for completing writing plans and revisions. Their system includes a set of cue cards for different purposes of writing, structured under five headings: *new idea, improve, elaborate, goals,* and *putting it together*. Each prompt is written on a notecard and drawn by learners working in small groups. The teacher makes use of two techniques, *soloing* and *co-investigation*. Soloing gives learners the opportunity to try out new procedures by themselves, then return to the group for critique and suggestions. Co-investigation is a process of using think-aloud protocols that allow learner and teacher to work together on writing activities. This allows for more direct modeling and immediate direction. Bereiter and Scardamalia (1987) have found up to tenfold gains in learning indicators with nearly every learner improving his/her writing through the intervention.

Reciprocal Teaching

Brown & Palinscar (1989) have developed a cooperative learning system for the teaching of reading, termed *Reciprocal Teaching*. The teacher and learners assemble in groups of 2 to 7 and read a paragraph together silently. A person assumes the "teacher" role and formulates a question on the paragraph. This question is addressed by the group, whose members are playing roles of *producer* and *critic* simultaneously. The "teacher" advances a summary, and makes a prediction or clarification, if any is needed. The role of teacher then rotates, and the group proceeds to the next paragraph in the text. Brown and colleagues have also developed a method of assessment, called *dynamic assessment*, based on successively increasing prompts. The Reciprocal Teaching method uses a combination of modeling, coaching, scaffolding, and fading to achieve impressive results, with learners showing dramatic gains in comprehension, retention, and far transfer over sustained periods.

Schoenfeld's Math Teaching

Schoenfeld (1985) studied methods for teaching math to college students. He developed a set of heuristics that were helpful in solving math problems. His method introduces those heuristics, as well as a set of control strategies and a productive belief system about math, to students. Like the writing and reading systems, Schoenfeld's systems includes explicit modeling of problem-solving strategies, and a series of structured exercises affording learner practice in large and small groups, as well as individually. He employs a tactic he calls "postmortem analysis," retracing the solution of recent problems, abstracting out the generalizable strategies and components. Unlike the writing and reading systems, Schoenfeld carefully selects and sequences practice cases to move learners into higher levels of skill. Another interesting technique is the equivalent to "stump the teacher," with time at the beginning of each class period devoted to learner-generated problems that the teacher is challenged to solve. Learners witnessing occasional false starts and dead ends of the teacher's solution can acquire a more appropriate belief structure about the nature of expert math problem solving. Schoenfeld's positive research findings support a growing body of math research suggesting the importance of acquiring a conceptual or schema-based representation of math problem solving.

Forecasting Apprenticeships

COMET (Cooperative Program for Operational Methodology Education and Training) is an inter-agency program that develops weather training for forecasters affiliated with the National Weather Service, the Air Weather Command, and the Navy. Interactive videodisc training modules developed for these forecasters are also made available to university meteorology departments across the nation. COMET's distance learning program is presently nearing beta testing of its first two modules, *Doppler Interpretation* and *Convection Initiation*. The Collins-Brown cognitive apprenticeship model provides the conceptual foundation for the module series. Each module uses optical laserdisc, CD-ROM, and object-oriented programming to simulate a forecaster workstation and provide forecasting practice under representative conditions. The elements of the cognitive apprenticeship model are discussed below as they relate to the design of the *Convection Initiation* module.

Content. Cognitive apprenticeships teach domain or textbook knowledge, but they also make explicit the strategic knowledge needed to use that knowledge in solving real problems. A key goal for the COMET module was to provide authentic activities that required the forecaster to use situation-specific knowledge to make a forecast. There are no distinct "concept" lessons or "rule" lessons. Instead, a series of forecasting problems are presented with accompanying "conceptual models" and procedural "tutorials." In short, the domain and strategic content is made available to the learner in the immediate context of solving specific forecasting problems.

Methods. Computer-based instruction (CBI) is relatively well-suited to cognitive apprenticeship teaching methods. In addition to the modeling and scaffolding common to CBI, a growing number of toolkit-style programs and simulations allow for degrees of exploration. Reflection—comparing one's own problem-solving processes with others'—is possible though somewhat difficult with CBI. The COMET modules replicate a sophisticated forecasting workstation, where both learner and program may initiate actions toward problem solution, presentation, or feedback. However, because the module lacks a natural language interface, the interaction is somewhat constrained. A continuing challenge for CBI design is to develop methods of making instruction approach a continuous dialogue rather than a forced-choice, prefabricated path.

Sequence. As noted above, the sequencing rules of a cognitive apprenticeship may depend on the type of content being taught—e.g., hypertext exploration for schema building (Wilson & Jonassen, 1989) versus simple-to-complex case selection for skill building (*cf.* Reigeluth & Stein, 1983). The *Convection Initiation* module utilizes a progression of forecasting cases in a simple-to-complex order, similar to Schoenfeld's approach to math teaching; at the same time, a variety of hypertext structures—data, rules, definitions, etc.—are available to the learner on demand using hypertext access structures. This is to be expected: often a mix of well-structured problems and hypertext-like exploration is probably optimal for problem-solving instruction.

Sociology. The social aspects of the cognitive apprenticeship model seem to pose the greatest challenge for CBI design. From what we know about learning, social variables are powerful mediators in learning (e.g., Eckert, 1990; Salomon, Globerson, & Guterman, 1989). CBI is often administered on an individual basis, with a single learner engaged at a computer workstation. Although group work is a desirable option, sometimes it is not possible. The COMET weather forecasting modules are a case in point. Modules are to be completed on the job, but because forecasting offices are sometimes staffed with only 2 - 3 persons on duty at a time, learners must complete instruction individually during break times while others continue on the job. The design challenge is: how can we build in needed social reinforcement and convey a sense of community in what is essentially an individualized learning experience? To address the cognitive apprenticeship's social design, the *Convection Initiation* module incorporated several strategies, including:

1. The module begins with a forecasting office scenario. The learner is teamed with "Ron," a fellow forecaster, and immediately given a forecasting problem to solve. This same office scenario is used as a wrap-up, where the learner completes a 2-hour forecasting shift containing four forecasts.
2. Following the beginning office scenario, the learner is briefly introduced to a

panel of three forecasting experts. These experts serve as guides through the module.

3. Following each forecasting practice, one of the three experts provides feedback on the case in the form of an "expert answer." This is a 30 - 90 second explanation of the case. Meteorological data on-screen are highlighted with arrows; this is combined with either a CD audio overlay or audio-video sequence of the expert using a chromaboard, much like a TV weatherperson explaining a map. The module's beta testing will be completed over the spring and summer; we will report different effects of audio-only vs. chromaboard explanations. In either case, the personalized feedback from the actual experts should allow some social modeling to occur. The meteorological field is fairly small; moreover, there are no annual conventions typically attended by members of the field. Getting to know the forecasting experts through the IVD modules should help strengthen the sense of community within the field.
4. As stated above, the module concludes with an office-based simulation where the forecaster, teamed with "Ron," solves a series of realistic, time-based forecasting problems.

Through these efforts to make the module more personalized, the social elements needed to support good instruction are artificially created. We believe these compensating strategies will help improve the reception of the modules in the field, and improve the attitudes of learners completing the modules on an individual basis.

Summary and Conclusion

This paper has been concerned with the relationship between two related disciplines: cognitive psychology and instructional design. ID, the more applied discipline, faces the challenges of constantly re-inventing itself as new research in basic psychology sheds lights on learning processes. It is no cause for concern that ID models need continual self-review; indeed, there would be cause for concern if the situation were otherwise. To provide some sense of context, however, I would like to call attention to some basic principles of cognitive apprenticeship articulated by the philosopher Erasmus more than 500 years ago. In a letter to a student friend, Erasmus offers some advice:

> *Your first endeavor should be to choose the most learned teacher you can find, for it is impossible that one who is himself no scholar should make a scholar of anyone else. As soon as you find him, make every effort to see that he acquires the feelings of a father towards you, and you in turn those of a son towards him .... Secondly, you should give him attention and be regular in your work for him, for the talents of students are sometimes ruined by violent effort, whereas regularity in work has lasting effect just because of its temperance and produces by daily practice a greater result than you would suppose .... A constant element of enjoyment must be mingled with our studies so that we think of learning as a game rather than a form of drudgery, for no activity can be continued for long if it does not to some extent afford pleasure to the participant.*
>
> *Listen to your teacher's explanations not only attentively but eagerly. Do not be satisfied simply to follow his discourse with an alert mind; try now and then to anticipate the direction of his thought .... Write down his most important utterances, for writing is the most faithful custodian of words. On the other hand, avoid trusting it too much .... The contests of minds in what we may call their wrestling ring are especially effective for exhibiting, stimulating, and enlarging the sinews of the human understanding. Do not be ashamed to ask questions if you are in doubt; or to be put right whenever you are wrong.*
>
> Erasmus (1974, pp. 114–115)

At a time when terms like *metacognition*, *scaffolding* , and *cognitive apprenticeship* are being invented to describe the learning process, it is humbling to be reminded of the insights of former paradigms. Instructional-design theorists may chafe at the continuing need to revise their theories in light of advances in psychological theory, but it is good for both fields for the dialogue to continue. Indeed, the interaction between basic psychology and applied instructional design can be expected to continue for some time to come.

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