It Takes Expertise to Make Expertise:

Some Thoughts about Why and How and

Reflections on the Themes in Chapters 15-18

John D. Bransford & Daniel L. Schwartz

University of Washington Stanford University

Corresponding Author:
John Bransford, PhD
210 Miller Hall, Box 353600
College of Education
University of Washington
Seattle, WA 98195-3600
(206) 616-4480
bransj@u.washington.edu

It Takes Expertise to Make Expertise:

Some Thoughts about Why and How

We have been asked to discuss the chapters in Section 4, which focus on descriptions and measurements of the acquisition of skilled and expert performances. The chapters in this section (and the book in general) make it clear that the field has built upon, yet gone beyond, the classic research studies that compared expert and novice performances (Chi, Feltovich and Glaser, 1981; NRC, 2000). The emphasis has turned to the development of expertise, and to objective approaches to its measurement. The progress in moving from retrospective to prospective assessments of expertise development is truly exemplary and critical to defining effective learning conditions.

As we considered what we might say about this book's discussions of expertise development, we were reminded of a graduate student in the learning sciences who once asked us to complete the following statement: *"Practice makes per_____."* Expecting a possible trick question we paused for a moment. Eventually we said "*perfect*"; it seemed like the only choice.

The graduate student chuckled. He had taught kindergarten and explained "Practice makes permanent, not perfect". For example, if you let young children hold their pencils incorrectly when they write, they can easily become efficient at doing the wrong kinds of things.

This simple example suggests that "it takes expertise to make expertise," and this idea fits well with the theory and research discussed in this volume. For example, Ericsson (Chapter 18) and Baker (Chapter 15) make the important argument that fixed psychological traits are not sufficient for predicting expertise, so contextual supports must be important.

VanLehn and van de Sande (Chapter 17) and Boshuizen (Chapter 16) explicitly discuss instructional conditions that develop expertise.

The idea that "it takes expertise to make expertise" becomes clear to anyone who has been highly motivated to learn something new yet lacks access to experts who can help them. For example, one of us (JB) has written about an experiment where, after moving to a house on a river, he tried to learn to fish for bass through "discovery learning," then by consulting some books, then by consulting local experts (see Bransford, Slowinski, et al., in press). Without access to expertise, his rates of success (catching bass) would have been so low that he would undoubtedly have soon given up.

Two Kinds of Expertise

There are two different kinds of expertise involved in the idea that "it takes expertise to make expertise". There is learning expertise and teaching expertise.

Learning Expertise

Learning expertise involves the degree to which would-be experts continually attempt to refine their skills and attitudes toward learning – skills and attitudes that include practicing, self monitoring, and finding ways to avoid plateaus and move to the next level. Ericsson's studies of "deliberate practice" provide powerful examples of the kinds of activities individuals engage in to get better. These ideas resonate with the work of Hatano and Inagaki (1986) on "adaptive" rather than routine experts (see also Lin, Schwartz & Bransford, 2007).

In the work of both Ericsson and Hatano and Inagaki, effective learners make use of existing resources to help them improve. They read books (on chess for example), seek help from others, experiment with their environments, and "try on" new ideas to see if they help them make progress (e.g. in fishing, playing music, and playing chess). Over time, effective learners presumably internalize many resources from their culture (Vygotsky, 1987) and become better at knowing how to gauge and improve their progress.

There seems to be a strong social component to the learning process that appears worthy of further articulation by expertise researchers. For example, Tiger Woods hired a coach to help him rebuild his swing (e.g. http://sportscenteraustin.blogs.com/the_view/2005/05/tiger_woods_why.html). Had he failed to do so he would probably be one of Ericsson's examples of "very competent but not great". But without the coach, this change in behavior would undoubtedly have been very difficult and, most probably, impossible. What it means for a student or player to be "coachable" probably depends greatly on social issues of identity and affect as much as cognitive issues (e.g., Barron, 2004).

Teaching Expertise

Teaching expertise represents the second kind of expertise involved in the idea that "it takes expertise to make expertise". Teaching expertise can involve a variety of forms including coaches (sometimes a set of coaches with different kinds of expertise), well-written strategy books, designed videos, school curricula, and computer programs such as intelligent tutors. There is a sizeable literature demonstrating that simply being an expert in an area does not guarantee that one is good at teaching that expertise to others (e.g. Nathan & Petrosino, 2003, Schoenfeld et al, 2007).

We had the opportunity to talk with a Tissu expert who also coaches young people in the practice. (Personal communication, Feb 1, 2008). The art of Tissu, originating in France and named for the fabric that is integral to this aerial dance form, involves the dexterity of a gymnast, the grace of a dancer, and the strength of an athlete. (See Figure 1 & www.silkaerial.com).

Figure 1 here

The Tissu expert notes the following about her teaching.

"The work is so challenging I like to give them positive feedback, incentive. If it's too hard, they will give up if they don't get some success. I like to start easy to get experience and some success. I can see that for some students it hurts or they are scared when they drop. Others want to learn trick after trick and that's great but what about pointing your toes?"

The teacher's experiences have taught her about individual differences. *"Some people need to see it done. Some students like me showing, some like telling, some like looking, watching. I know they won't be able to hear me when they are upside down. They won't know where right is when they are hanging upside down so I have to send them up knowing what to do."*

It is also noteworthy that the expert is continually developing her expertise as a teacher: *"The more I teach a move, the more I learn how to deconstruct it into smaller bites that are learned much more quickly. My communication becomes more efficient and effective creating greater student success."*

We asked the teacher if she regularly interacted with other Tissu teachers to improve her coaching. She explained: *"I do continue my own training with other tissu artists which definitely informs my teaching. I have not taken a formal teacher training in the fabric. However, I also work with a community of aerial performers. I was a dancer, a gymnast, an* *actress and I have taught in these areas as well."*

Feedback for Bi-directional Learning

Ideally, learners learn from teachers and teachers learn from learners. This adds a dynamic element to the idea that "it takes expertise to make expertise"; namely, that we need to develop systems that allow the continual development of both kinds of expertise.

Central to this goal is the need to examine different types of feedback cycles. We especially emphasize bi-directional cycles that are important not only for learners but also for teachers (including mentors and coaches) so that they can improve their abilities to help others learn.

Each of the chapters in this section highlights different types of feedback cycles. The chapter by Baker directly asks what types of knowledge can be measured by high-stakes tests that are diagnostic of expertise development. The feedback generated by these measures tends to go to decision makers, but not necessarily the learner. In our experiences in schools, feedback from these tests comes too late to serve as classroom-based formative assessments that can guide teachers, and even when schools create their on formative assessments they are often used by the teachers to gauge student progress but not used to help students learn to self-assess (Partners in Learning, 2006).

Boshuizen (Chapter 16) explores whether problem-based medical curricula affect subsequent medical expertise. He uses the feedback from research studies and their measures to inform curricular design. VanLehn and van de Sande (Chapter 17) consider how measures of learning can inform instruction in physics instruction. Their innovative proposal is that physics expertise involves the development of a finite space of qualitative knowledge that captures the main "inflection" points of mathematical formulas. In this work, the feedback cycle guides instructional decisions by the computer.

Ericsson (Chapter 18) points to feedback cycles that go directly to the learner. He convincingly argues that expertise development is characterized by deliberate practice where people work on problems that are hard and new, rather than business as usual. So, by this account, if we want to see who is on a trajectory to expertise, we can see who is engaging in deliberate practice and gaining useful feedback. However, for younger students in the early stages of learning especially, we also need to explore the social conditions that allow them to connect with people who can help them along the way.

If we were to place our bet on where to measure and enable expertise development, we would bet on bi-directional learning experiences that provide rich feedback to both learners and teachers (including coaches, computer systems, etc). The feedback may be cognitive in nature, but as Boshuizen's (Chapter 16) review of the literature indicates, conditions of feedback have broad affective implications as well. We explore additional issues of feedback below.

Problems with Low Quality Feedback Cycles

Baker (Chapter 15) discusses feedback as a prime example of the many different roles that measurement has played in the educational arena. One role of measurement is to predict who will be good at learning something; for example, mathematics or flying an airplane. Another role of measurement is to use it as a source of feedback to support learning. Baker notes that early work by Thorndike (1904) focused on this latter issue. One of our favorite Thorndike examples involves a study where he gave students hundreds of trials of practice drawing four-inch lines, but none of them improved. The reason was that they were blindfolded and received no feedback on their performances. Once the blindfolds were removed the students improved dramatically.

Thorndike’s example focuses on the effects of students being blindfolded. We have emphasized the importance of bi-directional feedback, and teachers can also blindfolded. Bickman and colleagues (Sapyta, Riemer, & Bickman, 2005) discuss this point in the context of wanting to learn archery:

If you are learning by yourself or with an instructor and are blindfolded, you have no information about where the arrow lands…. Intuitively, hiring a coach seems to be a better method than depending on trial and error to learn any number of different tasks. However, if neither the coach nor the student can see the target, improvement is limited because of the lack of feedback. (p. 147).

Note that this situation is different from the kindergarten teacher we discussed earlier who helped students learn to write with a pencil, or the Tissu expert working with high school students. In both of these cases, the teachers’ distances between what was being taught and what was being learned were very close. And the performance measures (writing, performing the tissue routines) were highly authentic as well. However, as Baker notes, often this is not the case. Many measures of learning are weak proxies for the actual performances and abilities to learn that we hope students will exhibit outside the classroom. This can provide both the students and the teachers with a false sense that they are performing well. VanLehn and van de Sande (Chapter 17) provide examples from physics, where students and teachers emphasize feedback from quantitative problems that do not reveal the lack of qualitative understanding necessary for expertise.

The “Top Gun” fighter training discussed by Chatham (Chapter 2) presents an excellent example where low-fidelity feedback of successful learning had dire consequences.

The failure of pilots in actual fights led trainers to employ mock battles with a "red team" that was equipped with the same airplanes and tactics as the enemy that the pilot trainees would eventually face. The high-fidelity feedback helped a great deal. Several examples of the effects of high fidelity feedback on teaching for expertise are provided below.

Research with Clinicians

Bickman and colleagues (Sapyta, Riemer, & Bickman, 2005) have explored the degree to which clinical therapists learn to get better over time, and they argue that most of them quickly hit a plateau of relatively moderate performance and stay there. Their argument is that the clinicians' opportunities for high quality feedback limit their abilities to improve. *In essence, therapists are trained, are supervised, and practice in the absence of information about client treatment response from objective sources. Examples of limited clinician ability to make accurate judgments without feedback are plentiful. Despite [this evidence], professionals are typically very confident of their ultimate clinical decisions (Garb, 1998). The accuracy of clinical judgments, even for those clients who stay in treatment for considerable periods, has also been called into question on the basis of the general human tendency to overvalue one's own work … Providing feedback that the client is doing well only confirms to the clinician that the treatment plan is working well. This finding is not surprising; in fact it is consistent with theories that describe feedback induced behavior change as the consequence of a discrepancy between the feedback information and some standard (Carver & Scheier, 1981)* (p. 147, Sapyta, Riemer, & Bickman, 2005).

Note that the lack of learning affects both the clinicians and the clients. It amounts to a double failure to learn.

Research with Language Therapists

Ann Michael is a language therapist who served for several years as a clinical supervisor of college students who were beginning a practicum in therapy for language-delayed children. The college students had all passed the required pre-clinical college courses including theories of language and their implications for therapy. Many had done extremely well in their course. Nevertheless, in the clinical setting, Michael saw almost no evidence that the students used their classroom knowledge in the therapy sessions. Instead they tended to fly by the seat of their pants. Michael concluded that the college course must have been very poorly taught.

Michael was later asked to teach that college course herself. She did what she thought was a highly competent job and was pleased with the general performance of the students on her tests. A year later, she encountered a number of her students once again—this time in the clinical practicum on language therapy. Much to her surprise and dismay, these students also showed almost no evidence of applying anything they had learned in their language course. Many could remember facts when explicitly asked about them, but they did not spontaneously draw on that knowledge to help them solve problems in the clinic.

This time around, Michael was reluctant to conclude that her college students performed poorly because of unmotivated or less-than-clinically knowledgeable instructors. Instead, she decided to explore problems with traditional approaches to instruction and to study ways to overcome them. She did this successfully in her Ph D thesis (using video cases in a special way; see Michael, Klee, Bransford & Warren, 1993). For present purposes, the important point is that she would not have realized the need to change her teaching without the opportunity to see the students attempt to use what they had learned to do something "real". She had moved from experiencing low fidelity to high fidelity feedback. The effects on her learning as a teacher, and eventually on her students' learning, were profound.

Problem Based Learning in Medicine

Several years after Michael conducted her study, one of us had the opportunity to visit Howard Barrows at the medical school in Springfield, Illinois, where he had brought his work on Problem Based Learning that he had begun in Canada. Boshuizen (Chapter 16) provides an excellent overview of Problem Based Learning (PBL) and the kinds of innovative thinking and research that it has spawned.

Upon meeting Dr Barrows we asked how the idea for PBL had emerged, and we discovered a story very similar to Michael's (although Barrow's discoveries had begun considerably earlier). Barrows noted that he taught a clinical assessment course and was shocked to find how ill prepared medical students were for this experience, even though they had passed very rigorous courses. One way to characterize the situation from a cognitive perspective is that the medical students had learned many facts and procedures but had not acquired the kinds of organized knowledge and understandings that prepared them for strategic action. As Whitehead (1929) would have said, the students' knowledge tended to remain inert (see also Bransford, Franks, Vye, & Sherwood, 1989). VanLehn and van de Slade (this volume) discuss similar discoveries about physics teaching and learning. They note that students are often more adept at mathematical computations than they are at understanding the conceptual foundations needed for flexibility and accelerated future learning.

In all the cases noted above, the major point we emphasize is that none of these teaching and learning problems would have been discovered unless people had begun to create settings for high fidelity feedback that went beyond typical tests of piecemeal knowledge. These discoveries helped both the teachers and the students improve.

Work in Education

Teachers in schools of education and teachers in K-12 classrooms also face challenges of dealing with weak feedback proxies. Colleagues of ours in education have often made tongue-in-cheek comments about “Teachers with 20 years of experience and those who have 1 year of experience 20 times.” Ideally, teachers and teacher educators would see their students in action post -graduation. Like the experiences of Michael and Barrows (see above), they could get a better sense of which aspects of their instruction worked and which aspects need improving. But typical teachers teach many students. In practice, this kind of feedback can be difficult to gather.

Many researchers in teacher preparation institutions recognize this problem and are beginning to devise ways to create high fidelity feedback loops that give faculty a much clearer indication of what their students are taking away from the classroom and using in practice (Peck, Gallucci & Sloan, 2006). This includes a variety of activities such as visits by students who have graduated, responses by graduates to written teaching cases, and feedback from groups of professionals (e.g. local principals and superintendents) who provide valuable information about ways that graduates are and are not being prepared for the workplace.

One of the present authors (JB) made a significant change to his classes for prospective teachers after receiving feedback from a group of local principals who serve as an advisory board for the teacher preparation program at his university. The principals noted that the learning course, as well as subject matter methods courses, frequently appeared to use contrasting cases of “good” versus “less good” ways to teach particular kinds of subject matter. They liked this, but they also pointed out that it caused a problem. A case they pointed to was that many of the examples of poor ways to teach middle school science came from a textbook that the district was mandated to use! When students from the teacher preparation program saw this text being used in their schools they reacted negatively and did nothing but criticize. The principals explained that they were not fans of this text either, but since it was mandated they had no choice at the present point in time. They explained that they tried to help teachers find ways to use strong teaching strategies (e.g. teaching for understanding) even within the confines of this textbook. Ever since this session, the author who heard this feedback has changed his approach to helping people become "effective teachers in an imperfect world".

The work cited earlier by Peck and colleagues (Peck, Gallucci & Sloan, 2006) provide illustrations of implementations of feedback cycles for teacher educators that are more systemic and elaborate than the simple example noted above. Similarly, Bickman and colleagues (Sapyta, Riemer, & Bickman, 2005) discuss computerized systems that provide feedback to clinicians about key patient outcomes. The present authors are also working with an entire school system that is using the web to make teaching, learning and assessments (without student identification) public (Bransford, Copeland, Honig, Nelson, Mosborg, Gawel, Phillips, & Vye, in press) discussing the details of these innovations is beyond the scope of this paper. However, they all point to efforts to create the kinds of bi-directional feedback systems that can help both teachers and students continue to learn.

Standards of Expert Performance

The idea that feedback must be compared to some "standard" is crucial for discussions of its usefulness. To return to our kindergarten students who are learning to hold a pencil, the standard used as a basis for feedback plays a crucial role in helping them learn.

Recent studies of expertise, especially by Ericsson and colleagues (Ericsson, Charness, Feltovich, & Hoffman, 2006) have paid careful attention to finding authentic tasks that allow repeatable assessments of skilled performances. In golf, for example, attempting to sink a long putt is a frequently encountered part of play, and Ericsson and his colleagues have been able to measure this skill under standardized and controlled conditions.

The work by VanLehn and van de Sande (Chapter 17) in physics also has important implications for performance standards by focusing attention on key qualitative ideas that are assumed to serve as much better foundations for future learning than the typical "mile wide and inch deep" (or kilometer wide and centimeter deep) content and formulaic coverage that we see in many courses and texts (e.g., NRC, 2000; Wiggins & McTighe, 1997). In a similar manner, work in areas such as PBL is guided by standards for performance that go beyond mere declarative knowledge and involve the kinds of interview and assessment activities with patients that represent key aspects of professional medical work.

Knowledge of Performance Conditions

Having clear knowledge of performance conditions seems to be extremely important for both teachers and learners. Teachers who have this knowledge can create conditions that allow them to continually assess students' progress toward authentic tasks. Of course, this knowledge will not necessarily lead to these kinds of assessment behaviors. The early examples by Michael (who knew what it was like to be a language therapist) and Barrows (who knew what it was like to be in his area of clinical practice) demonstrate that they needed to experience a sense of disequilibria before rethinking how they taught and assessed.

Learners can also benefit from clear knowledge of performance conditions. They can better monitor their own understanding and hence take a “metacognitive” approach to learning, including knowing when to ask questions of clarification (e.g. NRC, 2000, Vye, Schwartz, Bransford, Barron, Zech & CTGV (1998). Sometimes, it can be valuable to let students experience performance conditions before demonstrating standards of expert performance. Research has demonstrated that, in some cases, there are advantages to first letting students experience the complexities of a situation and then providing information that helps them understand expert techniques in light of their earlier successes, difficulties and questions (e.g. Schwartz & Bransford, 1998).

Ideally, both teachers and learners have a strong sense of the performance conditions they are working towards and can continually inform one another about the degree to which their current experiences are leading to increased learning. Often this does not happen, especially in school. To illustrate the issue, imagine a Top Gun red team training where the instructors were aware of the tactics of the enemy but did not make this information explicitly available to the pilots being trained. The pilots would presumably learn something from the experience, but probably not as much as if they were also helped to seek the kinds of information needed connect their experiences to specific enemy tactics. To draw an analogy to Judd’s (1908) classic studies on transfer, one can imagine that the “implicitly trained” pilots would not do as well as the “experience plus explicitly trained” pilots if the enemy later changed some key tactics and these could be analyzed and taken into account.

Stable and Variable Performance Conditions

It seems useful to ask how different conditions of performance might affect ideal approaches to teaching and assessment. For example, in a circus act like Tissu, the rope and the equipment remain constant from performance to performance and there is no opponent (as in chess and many other settings) that tries to knock one off the rope.

The importance of being able to rely on well-specified performance arenas is illustrated by the 2000 Olympics held in Sydney, Australia. After a number of gymnasts experienced great difficulty in the women's vault competition, it was discovered that the vault had been set 5 centimeters too low (See http://www.youtube.com/watch?v=q7bxa77ccmQ). In gymnastics, as in Tissu, the performance apparatus is assumed to be stable and fit very strict standards. Even slight deviations from these standards can cause deleterious effects.

In many areas of expertise, ideal performance cannot count on stable conditions. Preparing for rapidly changing conditions seems to be quite different than preparing for the (usually) predictable layout of the equipment to be used at a gymnastics meet or a Tissu exercise. The introduction to this book makes a strong statement about rapidly changing conditions:

"Developments in technology and software engineering are making many types of traditional jobs, such as book-keeping, accounting, routine design, and indexing of documents virtually obsolete (Rasmussen, 2000)…. Today's conditions of work require ongoing adaptations by employees and entrepreneurs to new demands and competitive opportunities through continuing education and training. … The competitive advantage of the traditional industrial countries is becoming increasingly dependent on their skilled workforce and research and development groups that are able to lead the development of new and improved products and then to be more flexible and reactive to changes in market demand. This, in turn, motivates increased efforts on supporting the development of professionals, in general, and especially by identifying experts and high-performers and providing them with the suitable learning

environments" (Ericsson et al., Chapter 1, p. 1).

This quotation focuses on flexibility and innovation, a focus that others have also emphasized (Bransford, 2007; Mead, Stephens, Richey, Bransford & Weusijana, 2007). The premium on flexibility and innovation in variable environments does not mean that learners and teachers should give up on efficiency in the pursuit of adaptability. When structured appropriately, they complement one another (e.g. Schwartz, Bransford & Sears, 2005). A balance between the two supports what Hatano and Inagaki (1986) have called “adaptive expertise” rather than "routine expertise."

Are their standards of performance that can help us develop the kinds of adaptive expertise that seem needed for the coming century? Our conjecture is that the answer is “yes”, but these standards look different from those that are typically used as test items. Baker’s chapter (this volume) on measurement makes similar arguments about the need to assess flexible abilities to learn. Our argument (see Schwartz, Bransford & Sears, 2005) is that typical test items retrospectively assess previously acquired schematized knowledge. This is important, of course, but more is needed for fast changing environments. People also need to adapt to new innovations or environmental changes that can cause momentary implementation dips and force them to move them away from their existing comfort zones. And people also need to learn to innovate on their own. An important aspect of developing expertise is learning to notice and look for new standards of expert performance, which is amplified in changing environments.

Our view is that measures of expertise must include measures of learning that ask how prepared people are to learn new information, develop new standards of performance, and to invent new tools and procedures that can help them “work smarter”. If we care about learning in everyday environments, we need to move beyond “sequestered problems solving” (SPS) assessments, where people solve problems shielded from opportunities to learn. Instead, it is more useful to look at how people use resources around them to support their learning. This includes the ability to experiment with objects in one’s environment, use technology to find and test information, and work with others in “distributed expertise” teams. From this perspective, the development of social networks of expertise becomes an important aspect of learning that is extremely important to encourage and assess (O'Mahony, Vye, Bransford, Richey, Dang, Lin, Soleiman, submitted).

The idea of assessing peoples’ “preparation for future learning” (rather than only assessing what was learned previously and is now being applied) brings us back to the issue of feedback and its importance for human adaptation. Most tests are feedback-free while people take them; there is no chance to explore, see what happens, and then invent a new strategy for trying again. We have argued elsewhere (Schwartz, Bransford, & Sears, 2005) that SPS (feedback free) assessments can create both false positives and false negatives. They can make some people look much better than they are because they received special instruction that aligned closely with the test items. Or, they can make people look worse than they are because they are excellent learners but did not have the specific learning opportunities necessary to do well on the sequestered test.

Non-interactive assessments in an interactive world can fail to reveal the different moves types of interactions that people use to support learning and the potentials for potential opportunities to further support learning and interaction. Nasir (in press), for example, examined learning in the context of playing dominos. She describes the rich interactive repertoires that children and experts use to help learn and teach the game of dominos.

Children can make partial moves that experts finish; experts can bluff to help children think ahead, children can directly ask for help, and so forth. While Nasir made her assessments of learning and interaction through careful observation, there are ways to make interactive assessments that are less labor intensive but still allow students and teachers to respond and adjust to feedback. Interactive assessments that depend on unaided observation can be difficult, but with technology, assessments can become interactive and we can begin to look at how students and teachers respond and adjust to feedback. For example, Lin has developed technology driven assessments that help students and teachers in diverse classrooms recognize and manage differences in their educational values (e.g., Lin, Schwartz, & Hatano, 2005). The main value of these assessments does not lie in the scores that people get on them, but in the productive, interactive discussions that allow new learning to occur.

A friend of ours, Dr. Bror Saxborg, kindly wrote us about an interactive assessment where he was allowed to ask questions, receive feedback, and use this information to learn so that he could craft his answer. He is an MD and a PH.D who also wanted to gain business experience. He found out that a major management firm was hiring people “out of field” (they were running short of good candidates from business schools) and went for an interview. Here is the account that he wrote for us:

“*I was interviewing with McKinsey and Co., a very well-known international management consulting company that had become interested in what they termed "non-traditional hires," people who did not have traditional business or MBA backgrounds, but who could learn. I think I stretched the edge of their definition: at the time I was being interviewed, I knew almost nothing about business - I was an M.D. - Ph.D. research type, who's first idea about "bonds" were chemical, and who'd assume that a "warrant" had something to do with the* *legal system.*

They had clearly instructed their interviewers to try to use non-business examples so as not to frighten off non-traditional folks like me. So this very nice partner at McKinsey who interviewed me gave me a case example of a ballet company, thinking this would surely be something that I could think about out loud. He began by asking me to help him think about the different factors that would go into the profit of a ballet company. My response to his question was, "I'll be glad to help you think this through, but you first need to give me a little help. Is profit the number you have AFTER you take away the costs, or before you take away the costs?" There was, admittedly, a longish pause, and he then said, "The number AFTER costs are taken away," and off I went - that's all I needed to know. They did, indeed, hire me, and ever after I looked back in wonder at the patience of this extremely senior and talented business consultant, who took the time to interview a complete know-nothing and, without batting an eye, helped fill in a little but important detail to let me show what I was likely to be able to do." (Saxborg, personal communication, 2007)

A number of members of the LIFE Center (Learning in Informal and Formal Environments http://life-slc.org/) are currently working to compare students' performances in non-interactive ("sequestered problem solving") test situations (like typical tests) with those that provide opportunities to seek information and feedback for new learning. For example, the team is designing interactive game-like environments (using Second LIFE, for example), that explore how prepared people are to design and continually improve "smart tools", protocols and strategies for accomplishing important tasks involving STEM disciplines (science, technology, engineering, mathematics). The assessments are interactive and hence provide opportunities for students to learn as they explore.

The studies are revealing many strengths that students bring to these tasks (including technology skills and content knowledge that guides their question asking as they use the technology). The studies also reveal some of the students' common misconceptions, and this is good rather than bad. It creates the kinds of bi-directional high-quality feedback loops (between teachers and students) that helps everyone learn more effectively.

These kinds of "preparation for future learning" assessments are clearly useful for formative assessments, but could they also be used for summative assessments? We think that the answer is yes and are working in this direction. Examples of early work along this line are discussed in Bransford, Zech, Schwartz, Barron, Vye & CTGV (1999) and further explored in Partners in Learning (2006).

Summary

To summarize, the chapters in this section of the book, and in the entire volume, provide rich discussions of issues of expertise *development.* From our perspective, a principle underlying all these lines of work can be summarized by the notion that "it takes expertise to make expertise". This helps emphasize that the process of expertise development is a social process where whose success is affected by (a) peoples' motivations to learn something that is important to them; (b) access to relevant teaching expertise; (c) the fidelity of the feedback cycles available to both teachers and learners and (d) the management of affect that accompanies struggles to truly improve.

Under the right set of configurations, both teachers (coaches, etc.) and learners will continue to improve throughout their lifetimes and avoid reaching premature plateaus in their performances. High quality feedback cycles seem to play highly important roles in this process; we have discussed several examples of changes in teaching and learning that accompanied changes from "low fidelity" to "high fidelity" glimpses of what students know and where able to do. Ultimately, we believe that high quality feedback cycles also need to include new kinds of assessments that better illuminate existing potentials of learners and teachers and provide new ways to define learning successes that go beyond traditional assessment practices. Efforts to more directly assess how prepared people are to tackle new *learning challenges* (how prepared they are for future learning) seems to be a useful avenue to pursue.

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Figure 1

A student learning the art of Tissue, and her teacher

Anders, insert the two pics here please?

Photos courtesy of Teasha Feldman (the student), Esther Edleman (the teacher), and Sue Feldman (the photographer)

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