The Cognitive Science of Skills and Learning

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Let me begin by saying that I think the goals set by the Partnership for 21st Century Skills (hereafter, P21) are for the most part good ones. I doubt many would disagree. We all want students to have a rich knowledge of core subjects (English, mathematics, arts, et al.), to be globally aware, to be critical thinkers, effective problem solvers, and so forth. Agreement on goals is a good beginning. The next question is how best to achieve these goals. Here, P21 and I part ways.

My training is in cognitive psychology and in neuroscience, and so I tend to see problems through those lenses. I see two assumptions about cognition in the P21 approach that cause me real concern about its likely success. I'm going to describe these assumptions and their consequences and in so doing elaborate on key points made by Dr. Hirsch and Dr. Ravitch.

The first assumption is that thinking skills and factual knowledge can be thought of as separate, an assumption that Dr. Hirsch also called into question. This characterization is true in most computing applications, which separate data structures (which we could liken to human knowledge) and processes that operate on them (which we could liken to human thinking skills); so long as the data are in a compatible format, the computing processes can operate on any data that are entered. In the human mind, however, knowledge and processing are more often interdependent.

This characterization is true for two reasons. First, one may possess a thinking skill, but fail to recognize that the skill should be applied-a failure due to a lack of appropriate background knowledge. For example, consider this problem (Watson, 1968):

The figure shows four cards. Each card has a letter on one side and a digit on the other side. You are to verify whether the following rule is true: If there is a vowel on one side, there is an even number on the other side. You should verify this rule by turning over the minimum number of cards.

The correct answer is that one must turn over the A card and the 3 card. This experiment has been repeated many times, and typically 10-15% of college students get the problem right.

Now consider this problem (Cheng & Holyoak, 1985).

You are an immigration officer at an international airport. Among the documents you must check is a form that on one side indicates whether a passenger is entering the country or is in transit through the country. The other side lists inoculations the patient has had in the last six months. You must make sure that if the form says "Entering" on one side, then the other side includes "cholera" among the list of diseases. Which of the following forms would you have to turn over to check?

In this experiment, 62% of college students got the right answer, which is to turn over the form at the far left, and the one at the far right. What is interesting about this finding is that the problem is logically identical the vowel/even-number problem. In each case, the card that gives people the most trouble is the one on the far right; in the context of the problem, this card embodies the logical form *modus tollens*:

If P, then Q
Not Q
Therefore, Not P

Or, to make it more concrete

To enter, you must be inoculated for cholera
This person is not inoculated for cholera
This person cannot enter

Why is modus tollens easy to spot in the second problem, but opaque to subjects in the first problem? Subjects in fact *know* how to solve the first problem; they just don't recognize the problem for what it is. The immigration problem is easy to recognize (and is therefore more often solved) because it is described in terms of a permission. A permission is a situation in which you must fulfill a precondition before you are allowed to do something. The students in this experiment have *lots* of knowledge about permissions, and so even though this particular rule is unfamiliar to them, they are able to think about it logically. The thinking skill that allows them to succeed in the second problem was there all along for the first problem, but they didn't recognize that the thinking skill was relevant because they didn't have the factual knowledge that allowed them to see the problem for what it is.

Now you might think "well, if they are solving the problem solely because it is a *permission*, then that doesn't seem like critical thinking. That seems like they are simply drawing on memory." That's exactly the point. *Modus tollens* is a logical form of deductive reasoning. What is more characteristic of critical thinking than the effective use of deductive reasoning? And this example shows that we can't say "this person knows how to apply *modus tollens*" or "that person hasn't learned *modus tollens*." Whether or not a person uses this logical form successfully depends on how the problem is framed. If the person recognizes the problem for what it is, the person will succeed. Otherwise, he or she will not. And recognizing the structure of the problem often relies on prior knowledge.

Prior knowledge is important not only for *recognizing* problem structure, but also for successfully *deploying* critical thinking skills. Let's take an example that is more typical of a classroom. Suppose a student is to design a science experiment and she chooses to investigate the effect of regular exercise on learning. The student has been taught that an experiment needs a control group, and so she appropriately designates a group of non-exercisers for comparison. She also knows that the control group is supposed to be just like the experimental group, the only difference being the critical variable (exercise vs. no exercise). Instruction in "critical thinking for science" will take her that far. But she needs some scientific knowledge to carry out her intention of creating two equivalent groups. For example, does the ratio of males to females need to be the same in the two groups? How about the ratio of left-handers to right-handers? Do the groups need to be matched for age? For race? For family income? The answers depend on the learning task that the student decides to use. The student needs some factual background knowledge about learning to determine how to set up her control group. The larger point I want to emphasize is that one might *know* that a critical thinking skill should be used, but still need factual knowledge in order to *use* that skill appropriately.

So let me summarize the first point: It's inaccurate to talk about skills and factual knowledge as separate. I often hear people say "Yes, yes, of course, knowledge is important. After all, you need something to think *about*." But there is more to it than that. Knowledge is not just something that skills operate on-knowledge is what enables skills to operate in the first place. (For a non-technical overview of this topic, see Willingham, 2007).

The second assumption that I see in the P21 documents is that-unlike the rest of us-teachers do not have cognitive limits. By declaring that teachers have "cognitive limits" I don't mean that teachers aren't smart enough. I know that there are education reforms predicated on this idea, but I reject it, and I think the data indicate that teachers are, on average, a bright group of people. "Cognitive limits" is a term cognitive psychologists use to refer to the fact that humans can only pay attention to a fraction of the stimuli that

continually bombard us, that our memories are imperfect, that our ability to solve problems may be compromised when we are under stress, and so on. Those are examples of cognitive limits.

Naturally, I'm sure that the authors of the P21 documents don't really believe that teachers, unique to the human species, are not subject to cognitive limits. But there is a disquieting failure to recognize what a difficult task teachers have been set by the plan, and what the consequences are likely to be. I'm particularly thinking about the pedagogical strategies that teachers will be encouraged to use. For example, the *21st Century Curriculum and Instruction* white paper provides two examples of approaches that it describes as "effective ways to enhance learning of both skills and content." These are **problem-based learning** (in which "students investigate rich and challenging issues and topics, often in the context of real world problems") and **cooperative learning** (in which students are organized into heterogeneous groups to work together).

It is important to note that teachers are already well aware of these methods. Indeed, a glance at standard textbooks on pedagogy designed for future teachers (e.g., Borich, 2007; Lang & Evans, 2006) shows that these methods are featured prominently and are described as effective. Less prominently featured is the method usually called **teacher-directed whole class instruction**, in which the teacher leads the class through a lesson, usually with the teacher doing most of the talking. In most textbooks, this method is described as having its place, but it is not highly regarded. Held in still lower esteem is **seatwork**, in which students work individually at their desks (reading, completing worksheets and the like), supervised by the teacher. Textbooks for teachers often warn that seatwork should be used sparingly, because there is a real danger that it will be mere busy work.

The data, although thinner than one might expect, indicates that teachers believe what they are taught, and think that more student-centered methods (such as problem-based learning and cooperative learning) are best for student achievement (Clift & Brady, 2005). But observational studies measuring what actually happens in classrooms show that teachers very seldom use these methods. Instead, they use teacher-directed whole class instruction and they use seatwork. Those two methods account for more than 90% of the academic time of American 5th graders, according to a recent study (Pianta, et al, 2007). Thus, teachers believe the best lessons are the ones in which students work together, and have some voice in the direction of the lesson. Yet teachers use strategies in which students are on their own, and teachers are very much in control. Why?

I have talked with many professors at schools of education and they almost always have the same attribution-tradition. They believe that parents and many administrators are leery of what they see as soft methods. Teachers may begin their careers as idealists who want to use these teaching methods, but they eventually buckle under the pressure and conform to what other teachers do and what parents expect, and what is, indeed, familiar to the teachers themselves. I expect that inertia plays some role, but I think that there is more to it than that. Teachers are, indeed, idealists and most are quite protective of their autonomy. Given that they believe these methods are effective, I can't help but think that at least *some* teachers would resist the pressure and use them.

John Goodlad (1984) and Mary Kennedy (2005) offer a different reason that I find compelling. They emphasize that teacher-directed whole class instruction and seatwork are both ideal for classroom management. In the former, one person talks at a time, and in the latter, no one should be talking at all. In addition, the teacher knows where everyone should be looking: At the person speaking for whole-class instruction, and at one's desk for seatwork. Humans are exquisitely sensitive to gaze direction (e.g., Von Grunau & Anston, 1995), so these methods make it quite simple for the teacher to know if someone is not paying attention. It is much harder for the teacher to monitor the class when using methods like problem-based or cooperative learning. Kennedy argues that teachers are very concerned about lesson momentum, that is, to keep the lesson moving according to plan. Threats to momentum include distractions, or students not understanding what they are to do next. Momentum is easier to maintain if all students on the same page.

There is another factor at work. Lesson plans like problem-based learning are not only more difficult for the teacher from a classroom-management perspective, they are more demanding of the teacher cognitively, a fact that has been noted by many education researchers from John Dewey (1938) to Michael Pressey (1995). I believe this cognitive demand has not been taken as seriously as it should be. The teacher needs to know more when using these methods, and to make decisions about instruction more rapidly, and on the spot.

For example, suppose that students are reading Camus' *The Stranger*. A teacher might plan a class discussion of the book as follows. First, he'll be sure that everyone understands the basic events of the plot. Next he'll ask students to consider Camus' perspective on the absurdity of human existence; why does Meursault, the novel's main character, feel such despair and emptiness? Next, he'll try to make the themes in the novel more personally relevant; we are all in the same situation as Meursault, so why don't all of us feel empty and despairing? What are our defenses against these feelings, and why do these defenses fail Meursault? A teacher with this lesson plan can foresee fairly well the nature of the discussion that will follow. He also can predict what he will need to know for the lesson-the general topics of questions that students might raise. And because he will tightly control the pace and direction of the lesson, he can plan everything in advance.

Now consider an alternative lesson plan. The teacher will divide the students into heterogeneous groups. Each group is to select a theme of the novel that they will further study over the next two weeks, and then present their findings to the class, using whatever creative vehicle they choose, be it a play, artwork, a radio program, and so forth. That the teacher empowers the students to follow their interests is wonderful. But it could also be somewhat intimidating for the teacher. In addition to the classroom management issues raised before, consider the increased demands on the teacher's knowledge. One group is curious about existentialism. Another wants to study the relations of the French and Arabs in 1930's Algeria. A third wants to know about the influence of Sartre and of Hemingway on Camus. The teacher may be uncomfortable with his ability to guide these diverse groups effectively. Can he help students find appropriate source materials, and to differentiate between high-quality and low-quality sources on the internet on all of these topics? In addition, the cognitive demand on the teacher during class is high, and so are the stakes. For example, as student groups generate ideas for their projects, he must make a quick decision as to whether it is appropriate: Will students find enough material, or have they selected too broad a topic? Is their topic too advanced for them to handle, or can they do something similar that is a bit easier? Should he make suggestions for a new topic or let them try to figure it out on their own?

What are the likely consequences of the two incorrect assumptions I have described? If one believes that skill and knowledge are separate, it is a short step to the conclusion that cognitive skills can be practiced independently of knowledge. And indeed, on page 19 of the P21 "Intellectual and Policy Foundations Document" the claim is made: "Critical thinking is a skill that can be taught, practiced, and mastered." If a teacher tries a critical thinking task but the students find it difficult because they lack the required knowledge, might she not conclude that the next time the skill should be practiced in the context of a more familiar domain-instead of analyzing original documents from the Great Depression, perhaps they can analyze documents from their own, contemporary culture. After all, once the analytic skill is developed, they can always pick up the facts elsewhere. This attitude is reinforced in the "Intellectual and Policy Foundations" of 21st Century Skills document when it says, "With instant access to facts, for instance, schools are able to reconceive the role of memorization, and focus more on higher order skills such as analysis, synthesis, and evaluation" (p. 6). But as I've described, higher order skills do not operate in isolation from factual knowledge. **Everyone understands that memorizing facts without skills is not enriching. People forget that training skills without facts doesn't work.**

The second assumption made is that teachers' cognitive limits do not pose a serious problem. I believe that the history of education indicates otherwise, as Dr. Ravitch's presentation showed convincingly. I imagine that proponents of P21 might argue that terrific lesson plans and professional development will be offered. That will indeed reduce the severity of the problem, but it will not solve it completely. The difficulty in implementing these teaching methods is inherent in the methods themselves. Then too, more specific lesson planning would alleviate some of the cognitive burden, but would run a real risk of

alienating teachers because of their perceived loss of autonomy. This is not an easy balance to strike, and I don't think that P21 recognizes the depth of this problem.

It's important to keep perspective on the status of evidence for the P21 program. There are not data regarding the efficacy of the program collected from classrooms. So in a very real sense the ten participating states have agreed to be guinea pigs in a grand experiment that will see whether or not this works. What is being offered as evidence that it's likely to work is a characterization of the mind that comes mostly from laboratory experiments. I am claiming that that characterization contains errors that considerably reduce the probability that the P21 program will work as promised once implemented.

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