Systematically Using Powerful Learning Environments To Accelerate the Learning of Disadvantaged Students in Grades 4-8

by:

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Introduction

The biggest problem in American education is the decline of educational performance that occurs to educationally disadvantaged students in grades 4-8. Even when such students make gains in grades 1-3, their performance tends to stabilize in the fourth grade and then start to decline, leading all too often to dropping out. School reform efforts have been of little help, and may even have made the problems worse. [1] As this chapter was being written another national study is released that once again shows that Title I is having little effect in closing learning gaps.[2] Indeed, few educational practices have been validated with educationally disadvantaged students after the third grade. As a result, whenever the government periodically decides to make education a priority it focuses on 'getting students off to a good start' in grades 1-2. Yet such efforts never seem to lead to sustained improvements later on.

Most excuses for the failure of reforms to have much affect after the third grade are philosophical and sociological in nature, e.g., hormones, peer pressure, etc. However, I believe that there is something much more systematic and cognitively based that causes educational failure after the third grade.

My own approach to trying to increase learning on a large scale after the third grade has been to design and test more powerful learning environments. Over the past 18 years I have developed and experimented with: a) the Higher Order Thinking Skills (HOTS) program that replaces all the supplemental remedial work provided to Title I and Learning Disabled (LD) students with challenging thinking development activities, and b) SuperMath, a new two year pre-algebra curriculum. HOTS develops the general thinking skills of Title I and LD students, i.e., enables them to internalize a fundamental sense of how to work with any idea as opposed to thinking about formal classroom content. SuperMath, on the other hand, is a thinking in content curriculum that uses a constructivist, problem solving approach to learning math.

Over the course of 18 years the HOTS program has expanded to 2,000 sites. It has been successful in producing high levels of a wide variety of learning outcomes in grades 4-8. (Research with SuperMath is just beginning.) Some of the results will be described later.

Once we knew that HOTS worked we began to try to understand why it worked and who it worked with. Over time we tapped our teachers' and administrators' experiences, impressions, and data on a large scale to develop a deeper understanding. We looked for patterns in what we were finding from reports from teachers and administrators around the country. I refer to this approach to research as 'pattern sense making', i.e., trying to find the patterns in massive information inflows. This form of research can also be described as large-scale anthropological research.

We learned from this research, to our pleasant surprise, that the program worked with Native American students and most LD students. We began to wonder why a program designed for Title I students also worked for LD students. At the same time, we began to realize that HOTS did not work for about 15-20% of the students served and began to wonder why. Out of this learning and wondering a clear pattern began to emerge. As the hypotheses were sustained, this research began to generate fundamental knowledge about the hidden learning needs of students that led to a new explanation about the reasons for reform failure and that provided insight into how to do substantially better.

This chapter will present things in a backwards fashion. Part I will describe the conclusions reached from the pattern sense making research that unlock the puzzle of how to produce learning in educationally disadvantaged students in grades 4-8, and explain why current reforms are not working. Part II will briefly describe the rationale behind the HOTS program and how the learning environments that produced these conclusions were designed.

PART I

The Situational Mechanisms for Producing Learning in Grades 4-8

The most important factor in the decline of academic performance of educationally disadvantaged students after the third grade is the growing sophistication of the school's curriculum. Learning strategies that are successful earlier are no longer sufficient and may even impede learning after the third grade. Producing learning after the third grade requires much more sophisticated interventions than are generally available, and applying such interventions in a systematic and intensive way that focuses on specific learning needs. The current fashionable approach to reform, which is everyone doing their own thing and treating all students the same in the name of site-based management, collaborative participation, learning communities, full inclusion, equity, etc., are not likely to work after the third grade.

Producing learning after the third grade requires the use of sophisticated learning environments, A quality learning environment is a system that consistently provides sophisticated forms of student-teacher interactions over a significant period of time. Contrast this with what is seen in the typical classroom with a substantial number of educationally disadvantaged students. A teacher either asks simple questions to bored students, or when an occasional difficult question is asked, the same few students participate. Interaction is minimal for most students.

A powerful learning environment requires a creative, yet detailed, curriculum that incorporates some form of conversational system, and a very good teacher who is trained to teach differently. Few existing curricula or programs can meet this standard. At the same time, it appears that to be effective even sophisticated learning environments have to be applied in a focused, situational way that is targeted to learning needs. Research around the use of the HOTS learning environment found the following key situational effectiveness parameters:

Finding #1: The key learning problems of educationally disadvantaged students are very different K-3 and 4-8, and require totally different approaches. Continuing the same approach that has been effective in grades K-3 to the later grades will actually cause scores to drop.

The biggest learning problem in K-3 is content knowledge deficit, i.e., students do not know letters, numbers, etc. The biggest learning problem after the third grade is that students do not understand understanding, i.e., they do not begin to understand how to deal with ideas, generalizations, or abstractions.

This finding suggests that helping students in grades K-3 is not enough. An additional type of non content-based help is needed after the third grade. Indeed, many of the seeming content learning problems after the third grade are not really content learning problems but a symptom of the understanding deficit. For example, if a ***fifth grade*** Title I student is having trouble with reading and doing a variety of math problems, the conventional approach is to provide extra help in reading and math. However, a content reinforcement approach does not help much after the third grade because the content learning problems are probably a manifestation of the deeper problem—that students lacks a sense of how to organize and understand ideas. As such, students are unable to apply content which is force fed to them to problem solving situations or test items. (Indeed, claims by vendors of major gains after the third grade from direct content instruction approaches usually turn out to be true only for the specific test items that students have been taught to take. Change the test and scores drop dramatically since students cannot apply the rote information to an unfamiliar context.)

At this point it is important to step back from specific content help and spend the available time first developing a sense of understanding. A sense of understanding will generally enable students to learn content the first time it is taught.

Finding #2: Until a sense of understanding is developed, educationally disadvantaged students in grades 4-8 cannot succeed in thinking-in-content curricula. (This is the theory of cognitive underpinnings.)

Full development of the intellectual potential of educationally disadvantaged students requires a two-stage process. The first step is the development of a general sense of understanding. *This is the catalyst that enables them to learn everything else at a more sophisticated level.* The second step is to then place students into exemplary thinking-in-content curricula in a heterogeneous environment. The internalization of a sense of understanding enables the students to subsequently understand academic content. Eliminating the first step, and following the natural progressive urge to immediately place educationally disadvantaged students into thinking in content in the name of equity, does not work. This is probably the primary reason why the nobly intentioned discovery math and science movements of the mid sixties and early seventies did not work.

At the same time a sense of understanding cannot be produced via casual effort.

Finding #3: In stage one of intellectual development it takes 1.5-2 years to develop a sense of understanding through small group (5-13 students) sophisticated Socratic conversations provided in a *homogeneous* setting for 35-40 minutes a day.

The reason why such conversations have to be provided in a self-contained homogeneous environment (which at the elementary level means pullout) is that such conversation cannot be provided with sufficient intensity in a regular-sized classroom to overcome the understanding deficit. However, once students develop a sense of understanding they are able to benefit equally as other students from the more limited conversation in the regular classroom.

The natural reaction of educators to the news that the right learning environment can produce a sense of understanding with just 35-40 minutes of intensive sophisticated discussions a day is that if such activities provide so much benefit then all learning should be done this way. There are two problems with this perspective. First, while additional conversation does not hurt, providing more conversation does not seem to reduce the time it takes to develop a sense of understanding. Second, actually producing the needed activities are extremely difficult, and few schools have the resources and expertise to provide such activities throughout the school day. Actually, the fact that producing understanding requires so little time in the school day is good news. It can be done in a practical way using existing Federal funds. In addition, it is important to use traditional approaches to teaching and learning part of the school day.

Finding 4a: Developing a sense of understanding in a program such as HOTS simultaneously generates substantial improvement both in standardized tests scores and on a wide variety of other alternative measures of cognitive development.

Research has found that HOTS students do better on both traditional and alternative forms of assessment than control groups of Title I students. Close to 50 studies done over the years by schools and districts generally find HOTS students gaining twice the national average gains on both standardized reading and math tests (spring to spring testing) and three times the gains as control groups on the comprehension sections of standardized tests. In addition to basic skill gains, almost 15% of HOTS students nationally make honor role—suggesting that students are transferring the cognitive development to the learning of content.

A recent dissertation by Dr. Mary Ann Darmer confirms the apparent transfer effects.[3] Dr. Darmer measured the development of HOTS students in terms of gains in: a) reading comprehension, b) metacognition, c) writing, d) components of IQ, e) transfer to novel problem-solving tasks, and f) GPA. Of the 12 measures used in the study, HOTS students went up substantially in all, and overwhelmingly outperformed a control group of students in the same school in all the comparison. Indeed, the fifth grade control Title I students in the same school declined in reading comprehension and GPA.

This research suggests that the effects of developing a sense of understanding were so powerful that they produced transfer to gains in both content learning and problem solving, and the effects showed up on both traditional standardized tests as well as on alternative assessment. Particularly significant is the transfer to gains in GPA. HOTS students improved a whole letter grade on classroom content—even though there was almost no linkage between HOTS and classroom content. Counter intuitively, the control students declined in GPA despite being pulled out half as much and receiving help in the classroom. In other words, the more time that students spent in the classroom the worse they did in classroom academic performance. This disparity in classroom performance is a testament to the power of developing a sense of understanding.

By the way, the declines in reading scores and GPA for the control students confirms the typical research finding that the longer students are in Title I the worse they tend to do. Some have argued that this decline is because students either become dependent on the service, or become stigmatized, particularly by pullouts, or that the tests are inappropriate. None of these excuses are valid. The fact that the HOTS students from the same classrooms increased so dramatically in so many ways refutes those explanations. The simple truth is that students increase or decrease after the third grade as a function of the type of learning environment that is provided, and with the right type of learning environment both traditional and non-traditional measures increase. Such effects are true regardless of race or ethnicity.

That is not to say that HOTS students are guaranteed future success. What HOTS does is get students to the point where they have the skills to be successful players in the game of school and are able communicators and thinkers. They still need to maintain a desire to succeed.

Finding 4b: Most educationally disadvantaged students have high levels of intellectual ability.

Findings #5: Once students have either completed two years of HOTS, or are in their second year, a core of such students should be grouped *heterogeneously* in at least one exemplary thinking-in-content course. (This is stage 2 of the intellectual development process.)

In a pilot test of the two-stage model in a Denver school, Title I students were placed in HOTS in the sixth grade, and were then placed into the second year of HOTS as seventh graders, along with a heterogeneous grouped class of SuperMath. Some of the students had pre-test math scores in the 90th percentile, and some of the HOTS students were below the 12th percentile. The HOTS students held their own in SuperMath and made substantial test score gains. As one of the students noted, "It was neat to see how our thinking strategies could help in math." The high performing students stayed high. What was especially important was the bonding that occurred between the low performing students who had a weak math background but who had more experience in explaining ideas and representing them on the computer—and the high performing students who had a good math background but did not feel comfortable representing their ideas.

The above findings demonstrate that it is possible to accelerate the intellectual abilities of educationally disadvantaged students on a large scale. However, the conditions for producing such gains are highly situational. Good intentions or occasional access to good stuff is not sufficient. Developing the intellectual ability of educationally disadvantaged students requires a commitment to providing exemplary learning environments, sequenced as described, for a 3-4 year period. Global approaches to reform are too diffuse to meet this need. More systematic approaches are needed.

Why Reforms Fail After the Third Grade

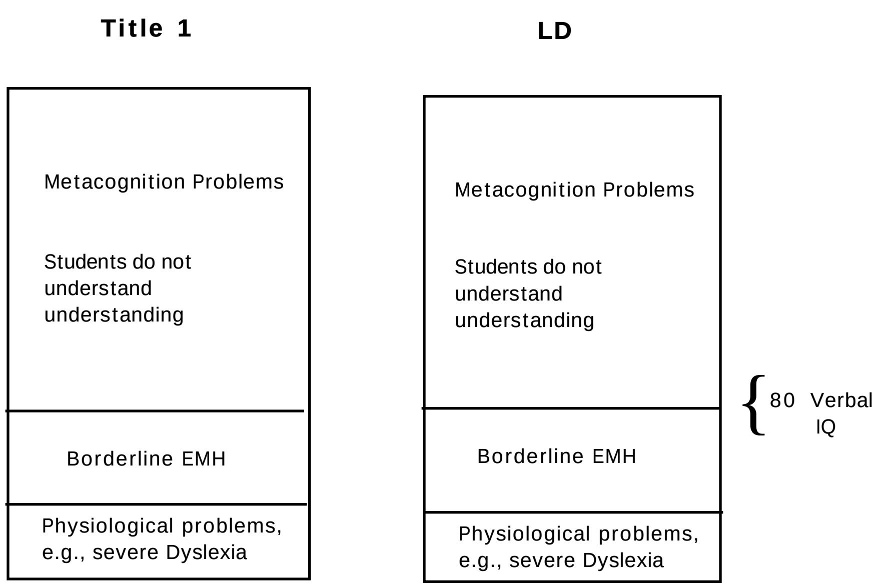
While developing a sense of understanding has proved to be very effective under the situated conditions of use, it is not successful with 15-20% of Title I and LD students. Why not?

The pattern sense making approach to research revealed that these populations are very heterogeneous in terms of their learning needs. Title I appears to have three distinct learning need populations. The majority, 75-85%, are high potential students who suffer from metacognition deficits (i.e., do not understand understanding). The second category (about 5-10%) is students who are borderline Educationally Mentally Handicapped (EMH). These students are truly significantly below average intelligence. They are in Title I only because Special Ed will not, or cannot afford to, serve them. The final category (about 5-10%) are students with physiological problems, mostly undiagnosed severe dyslexia and severe behavioral disorders. Many/most in this category are high potential students.

Learning Disabled also consists of three distinct learning needs populations. Guess which ones? That's right, the same three. The situation is depicted in Figure A.

FIGURE A

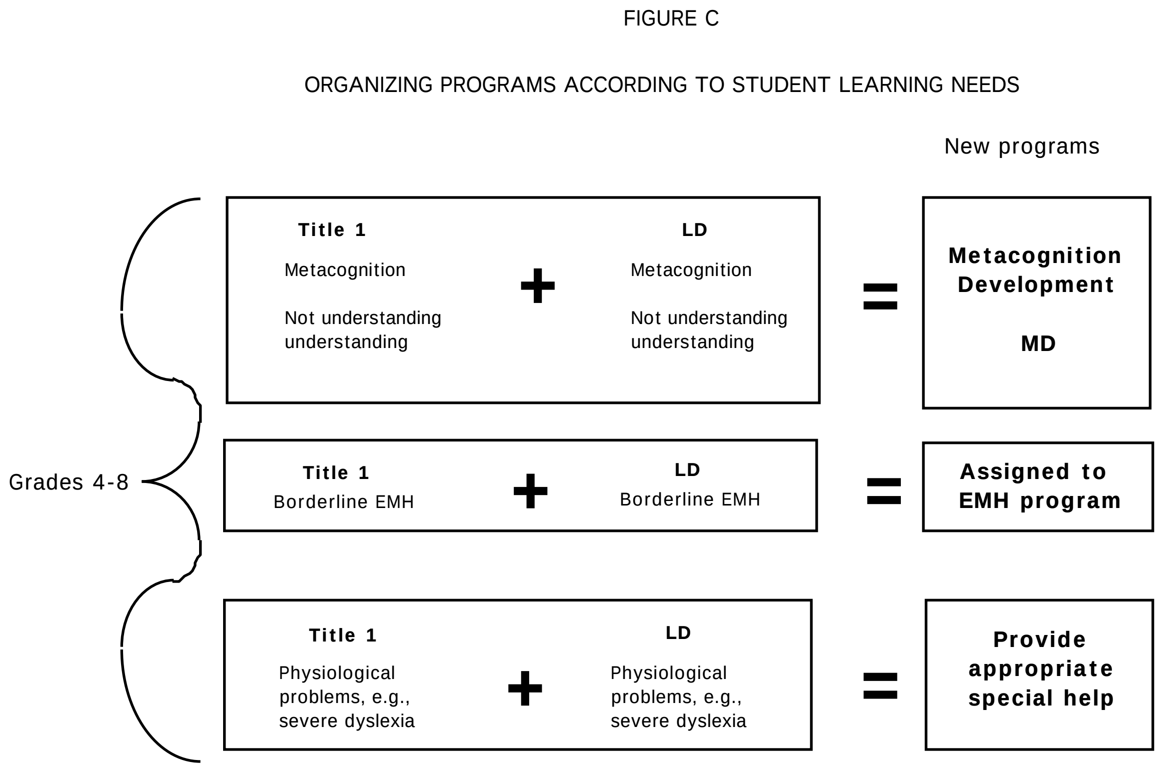
CATEGORIES OF FUNDAMENTAL LEARNING PROBLEMS
(Grades 4-7)



Not only have the patterns of large-scale effects from HOTS revealed a more detailed picture of distinct learning needs, but this method of research also provides a relatively precise way of predicting what students' needs are and how to help different students. For example, once LD students are lower than 80 verbal IQ they cross the boundary between benefiting from developing a sense of understanding and the metacognition development approach of HOTS stops having an effect.

This research clearly shows that the labels 'Title I' and 'LD' are merely legal contrivances that have nothing to do with student learning needs. Clearly, common sense would say that if we were truly interested in meeting students' needs, special services should be organized and funded according to the categories of: a) Metacognition development, b) borderline EMH, and c) physiologically challenged. In other words, the Title I and LD students whose primary learning need is to develop a sense of understanding should be grouped together and provided with the same service. This is illustrated in Figure B.

Figure B



The reason why HOTS only helps 80-85% of the students is that developing a sense of understanding will help both those Title I and LD students who need metacognition development help, but will be of little benefit to those who are borderline EMH or physiologically challenged. Reorganizing Federal help efforts as indicated in Figure B would enable all the special needs to be served, probably even within the same funding levels.

If the above findings are correct, then it is not surprising that most reforms have had little effect beyond the third grade. Schools/districts currently plan separately for Title I and LD with little or no coordination. In addition, they tend to implement a uniform approach to Title I across the grade levels. The uniform approach invariably is dominated by a content reinforcement strategy (regardless of whether in-class or pullout approaches are used)—and that is the crux of the problem.

A uniform content reinforcement approach works very well for the needs of K-3 students, and their scores increase. But *after the third grade* the content reinforcement at best meets the needs of only one category of the three categories learning needs—that of borderline EMH students. However, these represent a very small percentage of the overall Title I and LD population. At the same time, the content reinforcement approach retards the progress of those in the category of needing metacognition development help—which is the vast majority of students. As a result, current approaches after the third grade help 10% of the Title I and LD students and unintentionally retard the progress of 80%. Hence, overall scores increase K-3 and decline 4-8. In other words, the uniform content reinforcement approach to providing services does not meet the real learning needs of the majority of Title I or LD students in grades 4-8, hence scores decline. (Note! This explanation shows that contrary to popular opinion, the failure of early gains to be sustained is not a function of problems in K-3, but in shifting and varying needs in grades 4-8.)

Of course, when the field becomes disillusioned with uniform content approaches it shifts to uniform progressive reforms such as multi-disciplinary integration, schoolwide restructuring, pure whole language, etc. These reforms tend not to help because they are not situated enough and do not insure the actual delivery of a powerful learning environment under the conditions where they tend to be needed and effective. They are amorphous reforms that rely on good intentions, philosophy, advocacy and hope and therefore do not develop metacognition skills in the majority of Title I and LD students who need such skills. Indeed, ideological progressive reforms tend to make things worse by not only failing students in grades 4-8, but also tend to produce a decline in K-3 as a result of their de emphasis on formally teaching basic content.

Instead of uniform approaches, of either traditional or progressive approaches, we need more precise targeting and mixing of approaches in a more scientific way. The combination of some basic skill intervention early and a situated carefully specified progressive approach such as HOTS later on appears to be the best combination for most students.

This explanation for why interventions tend not to work after the third grade has nothing to do with empowering parents, schoolwide restructuring, site-based management, organizational renewal, multi-disciplinary curricula, authentic assessment, site-based management, student hormones, inappropriate tests, or any of the other recently touted reforms or cop-outs. Rather, the policy failure after the third grade is a result of not meeting student needs due to a misunderstanding of, and a lack of concern for, what those needs are.

PART II

The Rationale for the HOTS Program

HOTS got started 18 years ago. That period was the height of the drill and kill era, i.e., the belief that the best way to help educationally disadvantaged students was to drill them in basics until they got it right. That was also the time also when education started to become highly conscious about technology and starting incorporating microcomputers into the curriculum. The big technology debates of that era were whether schools should teach the Basic, Pascal, or Logo programming languages, and whether schools should buy Apple II, Pet Commodore, or Radio Shack TRS-80 computers. Schools largely responded to the new technology push by creating computer literacy curricula, i.e., the thousand facts that students needed to know about computers in grades K-8. The push was to prepare kids for the future by making them computer literate.

I was an opponent of computer literacy. My argument was that computers were going to become increasingly people literate, i.e., easier to use and requiring little technical knowledge. Therefore, teaching all this technical knowledge would be a waste of time. In addition, I felt that the *primary* impact of the computer was that it was going to obsolete routine work. Given the growing ubiquitousness of ever more powerful computers the only reason why employers would hire people was that an individual could perform uniquely human functions at high levels. These functions would be creative and innovative reasoning, human interaction skills, and artistic capabilities. Such jobs would require the manipulation of information and ideas in new ways. In other words, the challenge of technology was not to make everyone 'computer literate', but to make everyone 'highly literate' in the traditional sense. Anyone who was not highly literate and creative would be relegated low level jobs which it did not pay to automate, e.g., flipping burgers.

In a world in which technology raised the importance of literacy and its creative application, the equity issue to me was not equal access to the use of computers, but equal access to the development of thinking literacy. (I still retain this belief.) This access would determine who would have a chance to achieve the fruits of this society.

The beginning of the 80's was a heady time for anyone with technology experience. I was invited to speak at lots of conferences, mostly conferences on defining computer literacy. I was the one who said: "Don't do it." While my speeches would get applause my views were totally ignored; Until one day when I was approached after a speech by several individuals from a school outside of LA. They indicated that they were impressed with my ideas and that the drill approach was not working with their Title I students. But, given my remarks, they realized that even if the drill did work, the students would not be prepared to compete for the high paying jobs, which would be a tragedy since they felt that most of their students were bright. They felt that most of their students could work at high levels if somehow the school could find a way to reach them. They then asked me to design a Title I program for them based around thinking and computers—in which all drill was eliminated.

I agreed. We sat down in a room and everyone had a blank sheet of paper. The goal was to create a learning environment that could accelerate the intellectual development of Title I students by treating them as Gifted students. Instead of designing a Title I program, we would treat the students as though they were attending a fancy private school and would design the best possible educational experience that could be provided—even if they would obtain such an education for a small part of the day.

We then tried to figure out what to do. No one really knew how to pull it off. Thus the origin of HOTS was good intention informed by ignorance. However, as the program evolved, the initial ignorance turned out to be a strength because we did not get locked into clichés or rely on research, most of which I would come to discover in the later years was completely wrong. Rather, we relied on our own creativity, instincts, luck, metaphors (see the next section), and careful observation of the students to look for patterns in what seemed to work and what didn't.

Amazingly, the data from the first year were very positive. I began to wonder that if we could produce these kinds of results when we did not know what we were doing, what would happen if we knew what we were doing. (Fortunately, I didn't realize at the time that it would take at least another 10 years to really learn how to do it because I then might have given up.) Equally amazingly, other schools began to call wanting to try this approach. When I explained to them that I did not know what I was doing their reply invariably was: "It has got to work better than what we are now doing." It was a shock to me to discover that no one seemed to know how to help these students even though the government was spending $5-6 billion a year.

Over the years helping the disadvantaged students through a higher order thinking development approach became a mission. The 18 years went by fast and the program has spread to almost 2,000 schools. The thrill of discovery and the stories about student successes that arrive almost daily have been the big rewards.

In the early days of HOTS people argued that either a thinking development approach was illegal or that it could not work. Yet, we could clearly see that these students were bright, and that capitalizing on this intelligence by challenging them intellectually in ways that interested them was the best ways to not only prepare them for a non-routine world of work, but to also produce substantially higher levels of basic skills in grades 4-8. Today, the law has been changed to require that Title I services challenge students at high levels and be based on the best possible pedagogical practice. Unfortunately, while this has legitimized what we did in HOTS, current reformers have underestimated the need for a highly systematized approach to converting such good intentions into actual learning gains. As a result, HOTS remains unique in the systematization of state-of-the-art pedagogy and a novel approach to using computers on a large scale.

The Design of the HOTS and SuperMath Learning Environments

In the absence of how to design a program that intellectually challenged educationally disadvantaged students in a way that transferred to overall academic gains, the design process relied heavily on metaphors.   The first key metaphor for the design of the HOTS curriculum was dinnertable conversation. Conversation was selected because of the belief that early conversational experiences in the home develop a cultural sense of how adults in a given culture expect you to think and that such conversation is critical to general cognitive development. It was also believed that the absence of such conversation in the home and regular classroom was the primary cause for most of the learning problems.

HOTS was therefore designed to combine the use of Socratic conversation with computers. Computers were selected in order to design an interactive learning environment in which students could test their ideas as they thought of them, as well as to build upon their prior experience in learning through largely visual experiences. The curriculum would combine the familiar visual learning with the unfamiliar auditory and textual forms of learning.

The dinnertable conversation metaphor led to two major decisions. The first was that HOTS would be a general thinking program. In other words, the thinking would not be tied to the school's content, much as dinnertable conversation on the home is ad hoc, i.e., taking advantage of whatever a given day's experience provided the opportunity or incentive to talk about. The second key decision was not to use the computer as a tool or a content presentation mechanism, but rather as a 'metaphor for life'. In other words, the importance of software would not be what its explicit goal was, but rather whether experience with learning to use it would provide the opportunities to construct the types of systematic discussions that would promote cognitive growth—just as experiencing everyday life provides the basis for dinner table conversation in the home. Much as in the home, the daily similar form of conversation would produce the general cognitive growth. (In this approach technology is not integrated into the curriculum but becomes 'a' basis for designing the curriculum to begin with, and this is made possible by conceiving and implementing a more appropriate approach to using technology.)

Much as the power of dinnertable conversation derives from its consistency and appropriateness, the same characteristics were needed for HOTS conversations. Key elements of cognitive psychology were used to create a consistent form for the conversations that would model those thinking skills that appear to underlie all learning. The thinking skills chosen were:

a. **Metacognition**- Consciously applying strategies to solve problems
b. **Inference from context-** Figuring out unknown words and information from the surrounding information
c. **Decontextualization**- Generalizing ideas from one context to another
d. **Information synthesis**- Combining information from a variety of sources and identifying the key pieces of information needed to solve a problem

A detailed curriculum was developed that provided model conversations over a two year period to operationalize these skills. Metacognition had the biggest influence on the nature of the daily conversations that were mapped into the curriculum while decontextualization had the biggest impact on the structure of the curriculum and is what makes the HOTS curriculum unique. The focus on decontextualization came from our observations of student conversation in which they almost never seemed to generalize across contexts. In addition, the second key guiding metaphor was to think of the brain as a muscle. The way one improves the functioning of a muscle is to repeatedly use it in the way that it is designed to operate. How does the brain operate to store and use information? It creates linkages among related concepts. It was therefore decided to have the HOTS conversations mimic this process and have students constantly link ideas and discuss these linkages. The external conversations would model the internal operation of the brain 'muscle'.

The curriculum contained conversations that operationalized the above thinking skills as follows:

> **Metacognition** is produced by constantly asking students what strategy they used for solving a problem, how they knew the strategy is a good one, what strategies they found that did not work, how they could tell the strategy did not work, and to predict what a better strategy might be and to try it, etc.
>
> **Inference from context** is initiated in two ways. The first technique is to have students read interesting stories on the computer which combine text with graphics. Teachers then heighten student involvement by introducing the setting of the story in a dramatic fashion—such as warning the students that they will encounter many dangers in the story. The dramatic element builds high levels of engagement—a prerequisite for thinking to take place.
>
> The story chosen must also have words in key places that students do not understand. (It does not matter which words, or whether the words are in the students' regular curriculum.) Students are then told that every time they come to a word they do not understand they should: a) write down the sentence in which it appears, b) circle the word, and c) call the teacher over and make a guess about what the word means. They are also told to make a prediction of what will happen next in the story. (Twist-a-Plot stories are best.) The next day the teacher lists the sentences on the board and asks students to explain what they think the circled words mean from the reading and pictures, and why they think that. The conversations begin and student answers are probed. These rich conversations model prediction comprehension processes that good readers spontaneously engage in, and provide experience in information synthesis and metacognition, as well as in inference from context.
>
> The second technique for 'inference from context' is to build inference questions around unknown or ambiguous words in the instructions. Teachers constantly ask students to figure out what the unknown words mean, along with the strategy they used for figuring it out. The visual clues make it easier initially for students to build up confidence in their inference skills. Inference then becomes a normal part of learning how to use any piece of software.
>
> **Decontextualization** occurs in two ways. The first is by using words in the software that students are familiar with from their everyday experience, and having them make predictions about what they are likely to do in the context of that

program. For example, the graphics program 'DAZZLE DRAW' has a menu choice called 'flood fill'. Students are asked to predict what will happen if they make that choice based on what they know about the word 'flood'. Students then go to the computers to test their predictions. ('Flood Fill' fills an area of the screen with the color they chose.)

The second, and more powerful, decontextualization techniques is the use of a series of concepts that are discussed across many different contexts (software programs). For example, perspective is discussed when flying a hot-air balloon, writing a story from the perspective of an object when using a word processor, and discussing the perspective from which a character in a story is viewing a given situation. Students are then asked about how the use of the linkage concept in the current piece of software is the same and different than its in the prior program(s).

Information synthesis is done by creating situation where students have to use information from a variety of sources, or several different types of information, to answer a question.

The curriculum was developed by taking a piece of software that would be of interest to students (games and adventure stories are always good), and inventing a series of questions that provided practice in all of the above thinking skills and that link to the key linkage concepts discussed around other pieces of software. For example, in the popular simulation OREGON TRAIL, the explicit goal is for students to reach Oregon using the old Oregon trail. They have to budget food and supplies appropriately in order to make it safely through a variety of problems, such as attacks, bad weather and floods.

The curriculum then asks questions such as: "From what perspective are you looking at the wagon?" (Decontextualization of the use of 'perspective' as a key linkage concept), "What could the 'yoke' of an Ox be? (Inference from context), "What strategy did you use to reach Oregon?" (Metacognition), "Is anyone who traveled the trail alive today?" (Information synthesis.) These questions are incidental to the goal of reaching Oregon. They are based on words or phrases in the instructions. The questions are asked to initiate discussions which provide practice in the four key thinking skills. The quality, intensity, and consistency of discussions about the answers to these questions are far more important to the learning process than the quality of the software or successful use of the software.

It is this focus on conversations around tangential questions that consistently model key thinking processes that distinguishes the HOTS approach to using computers from Computer Assisted Instruction (CAI) or Integrated Learning Systems (ILS). The HOTS and SuperMath curricula represent clean sheet designs that explore how technology enables one to rethink the nature of curriculum which in turn inspires new conceptions of how to use technology.

The HOTS program evolved as a 35-40 minute self-contained period, 4-5 days a week for 1-2 years. The first half of the period is used for conversation, then the students are given a challenge to figure out on the computer. The key questions that need to be asked during the conversation portion are specified in the curriculum, along with the hoped for answer(s).

However, merely asking questions and getting answers does not produce sophisticated conversation. A Socratic system was developed based on extensive observation of student teacher interactions. The observations revealed the interaction situations where ambiguity broke down and teachers reverted to being dogmatic and directive instead of questioning. The HOTS Socratic system specifies key events and situations in conversations, and specifies strategies for the teacher to invent appropriate followup questioning probes that continues to place the student in a reflection mode that hopefully leads to self-generated understanding.

The key to making this work is a terrific teacher who is trained to teach differently. Metaphors from the theater were used to design the training. Prospective HOTS teachers go through an intensive small group five day training workshop. During the training they are not presented with theory. Rather, they slowly internalize the Socratic system via practicing teaching lessons to the other participants who act as students. As a result of the practice teaching they learn new reflexes for talking and listening to students, and develop expertise in the improvisation of followup probes to students' initial answers. They learn how to analyze everything that students say from an understanding point of view, and learn how to develop appropriate and creative followup questions that enable students to construct meaning. As such, the teachers learn how to teach differently around the curriculum that is designed from the ground up to support Socratic interactions.

Finally, all of this will not produce thinking unless students decide to exert mental energy. HOTS intrigues students through the use of the visual and culturally familiar stimulation of the computer's visuals and through the incorporation of drama. Each unit has a storyline, much as a play. Students are drawn into the activities through a variety of theatrical techniques. For example, some days the teachers are dressed in strange costumes.

All the above elements—drama, cognitive psychology, Socratic conversation, and computers—are systematically blended into a curriculum that has been tweaked over an extended period of time to produce a powerful, intensive, systematic learning environment. Students cannot hide from the small group conversation process, anymore than a child can hide at the dinnertable. The system pushes students into increasingly sophisticated forms of verbalization and strategizing around the use of textual information. The tasks are difficult, way beyond their developmental level. However, through the combined processes of experimentation and increasingly sophisticated reflection strategies, students develop confidence in their problem solving and communication skills.

The SuperMath program is a two year pre-Algebra program that is a new approach to designing a thinking in content curriculum, designed from the ground up around the capabilities of computers and Socratic dialogue. It uses a thinking-in-content, problem solving, constructivist approach to teaching traditional mathematics as well as some of the newer topics. Given the goal of creating a student-centered curriculum, the problem solving activities are not built around real world applications, but around fantasy environments that will be culturally familiar and interesting to students. Fantasy environments are used because there are precious few real world mathematical applications that are relevant to middle school students, and drawing examples from the adult world are a turn off.

Space permits only a brief description of the design of the HOTS and SuperMath Learning Environments. I have described them in more detail elsewhere.[4] However, I would like to provide just a few more insights into the design.

The basic design technique, which I call 'Learning Dramas', requires users to purchase software, use it in unintended ways, develop curriculum around such unintended uses, and then train teachers in advanced pedagogical techniques. This is a lot of work. In addition, ignoring the explicit goal of software and using it to create a setting around which to invent conversations seems counter-intuitive. However, the success of using technology in a non-explicit way has also been demonstrated by Dr. John Bransford.[5] He used laser disk technology to show a segment of Indiana Jones jumping across a pit (i.e., to set an interesting visual context that was familiar to students), followed by a discussion of the physical forces and mathematics that makes such an act possible. He found that using technology to provide visual settings to set a context for a follow-up discussion was a more effective way to teach math than using the technology to present the math, or even one-on-one instruction.

The design of learning dramas, however, is becoming more difficult due to the declining quality of software. As technology has gotten more powerful, developers are doing with software today what textbook publishers did in the 80's—dumbing down the language. In new software you point to icons and click, and then get more pictures, all of which is useless for promoting literacy. Indeed, where commercial software is used in HOTS, we usually use older versions and resist the newer, glossier, dumbed down versions. Unfortunately, as the older titles or versions are discontinued, we need to develop our own versions wherever possible.

Finally, the idea of creating HOTS and SuperMath as powerful learning environments around the use of technology was inspired by Seymour Papert's work.[6] Unfortunately, he thought that the use of sophisticated software such as Logo would produce a learning environment. That is not true. Both HOTS and SuperMath combine and systematize the many additional elements to construct a true learning environment, along with the use of technology not as a tool or as a deliverer of content or instruction, but rather as a setting that is a metaphor for 'life'.

The Role of Research in Program Design

Despite all the brave talk by academicians about the role of theory and research in program design, I found them to be of only marginal value. Theory is simply someone's best guess about something. Many theories abound. Which one is right? Indeed, even if you know that a theory is right, there could be a 100 different ways to operationalize it in a program and perhaps only 5 would work. The odds are against theory being of any major value. In addition, you quickly find that almost none of the theory that you might be interested in has any supporting data at all, let alone on a reasonable scale with the population that you are interested in.

Indeed, I would later discover that if I had initially made greater use of theory I would have gone down the wrong track. For example, I would have designed HOTS to be more linked to classroom/content work and would have tried to incorporate thinking into specific classroom content since virtually all cognitive theory believed that thinking development should evolve in content rather than as general thinking skills. HOTS has demonstrated that this theory is clearly wrong for educationally disadvantaged students. (It is probably true for the college students on whom most of the research was conducted.)

The most important step in design is selecting metaphors—which is largely a matter of instinct and luck. Once the metaphors have been selected you can make some judicious use of theory. Once we had decided to use the metaphor of the brain as a muscle it became clear that the information processing branch of psychology had the most relevant information, and within that branch there were a few ideas that had sufficient data to be credible. The only other literature which seemed to have a base in success with educationally disadvantaged students was the work in metacognition, even though it had generally not been used with grades 4-8. Within these areas of research a few selected studies were used to help flesh out some of the design details of how the metaphors would be implemented—a limited but valuable contribution.

Rather than using theory as the basis of design, it was fun to discover along the way which of the theorists had come to the same conclusions that the HOTS program was coming to, and then incorporate some of their ideas as modifications to the program. The work of L.S. Vygotsky was a notable example.

The irony is that a successful innovative learning environment has more value for generating theory (as indicated by the results in Part I), than theory has for its initial design.

Conclusions

HOTS has demonstrated that it is possible to design a highly creative yet directive learning environment that is consistently effective for educationally disadvantage on a large scale in grades 4-8—regardless of race, culture, and geographic location. It also demonstrated that it is possible to design learning environments that when provided for a small part of the school day produce transfer to a wide variety of academic, social, and cognitive gains. However, producing such a consistently powerful learning environment takes a great deal of time and luck in selecting the right metaphors and then implementing them the right way. In addition, to be effective the learning environment must match a powerful curriculum with a very good teacher who is trained to teach differently.

The HOTS curriculum worked because it set new standards for: a) blending creativity and directedness, b) conceptualizing how to use technology, c) providing a consistent and focused framework for enhancing general cognitive development, i.e., it successfully developed a *small* set of the most important thinking skills that have the greatest impact on literacy development as opposed to trying to cover a wide range of skills more superficially, d) combining good teaching with the use of technology, e) combining curricula with innovative training, and f) blending a disparate group of powerful metaphors.

HOTS has also demonstrated that it is possible to use an innovative program as a large scale research tool to generate: a) basic knowledge of learning needs, and b) knowledge of situational effectiveness. The former is valuable for trying to influence policy, while the latter knowledge is incorporated into the program's dissemination process—which further increased its effectiveness. For example, administrators are told which students are not helped by HOTS so that they can consider a more appropriate alternative approach for the others. *Indeed, research based integrity in the dissemination process is as important to the ultimate success of a program on a large scale as is the quality of the program's design!*

The HOTS experience indicates that while it is possible to accelerate the learning of educationally disadvantaged students in grades 4-8 in a systematic way on a large scale, there are situational parameters that guide the effectiveness of even powerful learning environments. Violate the key situational parameters and even the best learning environments will have little effect.

Unfortunately, current reforms violate all the parameters identified in Part I. There are cognitively based reasons why current reforms, including the new Title I legislation, have little effect. The learning problems identified within the Title I and LD populations are very real and represent substantial deficits that need to be addressed in specific ways. Effectively addressing these needs can only be done with targeted help based on appropriate situational knowledge—knowledge which I believe can only be generated from large-scale experience

This chapter has shown how to help the vast majority of the educationally disadvantaged population in grades 4-8. It has provided key guidelines for what needs to be done at the local and federal levels. We need to provide sustained powerful learning environments for metacognition deficient students for a 3-4 year period between grades 4-8 for a small part of the day. We also need to reorganize Federal and state supplemental funding so that it is targeted to the three different learning needs that have been identified.

While this chapter provides specific guidelines for policy and practice, I doubt that any of its recommendations will be considered by policy makers and practitioners in the foreseeable future. Under current conceptions of site-based management, every school does its own thing which makes sustaining a developmental approach for a targeted group of students almost impossible, At the Federal level, powerful interest groups want to protect their turf and funding and maintain the current legal and funding categories. As such, we may be destined to underserve yet another generation of educationally disadvantaged students who will never discover how bright they really are. We could be doing so much better.

NOTES

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