Era 3 Teaching and Learning: A Summary of Underlying Theory and Research[1]

By

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Overview

We contend that a core goal of schooling is to educate students for living in an Era 3, 21st century world[2]. Simply put, Era 1 was the agricultural era, and Era 2 was the industrial era. This new Era 3 world, the service, technology and knowledge based era, creates easy access to huge amounts of information via google and other search engines, increases communication via advanced technologies such as e-mail, wireless phones, texting and tweeting, i-pads, etc., and "flattens" worldwide communication systems via Internet and satellite connections. Knowledge-based, service-oriented and technologically advanced societies have different high-level job requirements, with a need for adults who can discover and investigate challenges, solve problems effectively, apply learning and adapt to new situations, think strategically, creatively and logically, and be technologically skillful.

The challenges of citizenship in a complex, global system require sophisticated understanding of economic, political, social and environmental issues, challenges and problems. And the complex career market means that students need to have the necessary "habits of mind" to persevere, be curious, do long term projects, as well as the ability to explore their strengths, develop talents, and plan for college and career next steps.

Given these challenges and changes, we believe that three important and critical principles of an Era 3, 21st century education are the following:

1. A primary goal of education is to help students uncover and understand important ideas through a coherent, meaningful, focused, interconnected curriculum.
2. "Deeper" learning experiences help students learn and use critical, key skills as well as learn and practice attitudes and behaviors needed in an Era 3 world, such as curiosity, perseverance, information processing and research, reading deeply for understanding, writing effectively, discussion skills, critical and creative thinking, problem solving and decision making, planning, and collaboration.
3. Student learning occurs, and evidence of learning is revealed, when students are interactively engaged in the learning process, and are able to apply, transfer and adapt knowledge and skills to new and novel situations through open-ended, authentic performances, tasks, and projects.

These three principles imply a different way of organizing educational experiences and student learning. Our view is that all subject areas should be given equal weight, and that each subject should be focused around core big ideas and essential questions that lead to thoughtful inquiry and understanding. "Learning progressions" enable students to revisit and refine key ideas and questions and build on previous learning. With a more focused curriculum comes opportunities for "deeper" learning that enable students to find and process information from a variety of sources, read for understanding, think logically and creatively, discuss issues, write frequently and reflectively, work collaboratively and the like. Performance tasks and projects enable students to inquire into open-ended challenges and to read and learn from a variety of sources, think more deeply, and transfer, apply and adapt their learning to new situations. Interdisciplinary learning experiences help students integrate learning and make connections among subject areas.

What is the research base that supports these educational principles? How do we know that educating for learning Era 3 21st century knowledge and skills will enhance student achievement? And what does the research suggest for classroom application? In the remainder of this article, we will review findings from cognitive psychology, studies of student achievement, and research on instruction that, taken together, lend strong support to Era 3, 21st century approaches to teaching and learning.

Research Findings from Cognitive Psychology

A summary of the past thirty years of research in learning and cognition supports the importance of learning with understanding and thoughtfulness (Bransford, Brown and Cocking, 2000, p. 8). For example, one avenue of this research explored the differences between novices and experts in various fields. Psychologists have learned that experts have more than a large body of information – they actually think differently from novices. "Usable knowledge is not the same as a mere list of disconnected facts" (p. 9); "…expertise requires well-organized knowledge of concepts, principles and procedures of inquiry" (p. 239). This research suggests that students, in order to become knowledgeable and competent in a field of study, should not only develop a solid foundation of factual knowledge but also develop a meaningful, well-organized conceptual framework of concepts and ideas.

A synthesis of cognitive research endorses the idea that deep understanding of critical subject matter transforms factual information into usable knowledge. Knowledge learned at the level of rote memory rarely transfers; transfer most likely occurs when the learner knows and understands underlying concepts and principles that can be applied to problems in new contexts. Significant, remembered learning is more likely to occur when students organize and connect knowledge into meaningful ideas that promotes transfer and application, rather than simply memorizing information from a text or a lecture. The research also supports the need for "thoughtfulness" as a significant part of the educational process – as a way for students to "mediate" and deepen their learning.

Figure one is our own synthesis of research-based learning principles, along with some of the implications of each principle for sound educational practice[3] [see next page]. These principles suggest that learning best occurs when it is purposeful and relevant; when students have the opportunity to organize knowledge into meaningful "chunks" to develop core ideas; when they have a chance to think in complex ways; when they have a chance to apply, transfer and adapt learning to new situations and problems; when they can connect learning to what they already know; when they understand how their values and attitudes influence learning; when they can regularly revisit ideas and skills learned and deepen learning over time, when they can learn in social, collaborative settings; when regular, timely feedback is frequently given to students; and when learning preferences and interests are taken into account in the learning process.

Achievement Research

School Level Factors That Influence Achievement

Marzano (2003) conducted some seminal meta-research to determine what school-level factors influence achievement. His analysis concluded that the top two factors are the following:

1. Guaranteed and viable curriculum;
2. Challenging goals and effective feedback

These two factors, taken together, suggest that a more focused curriculum, with fewer topics and learning goals that challenge students and provide time for deeper learning, is a significant factor in successful achievement. Effective feedback also requires more time

Figure 1: A Synthesis of Research-Based Learning Principles

1. Learning is purposeful and contextual. *Therefore, students should be helped to see the purpose in what they are asked to learn. Learning should be framed by relevant questions, meaningful challenges, and authentic applications.*

2. Experts organize or chunk their knowledge around transferable core concepts ("big ideas") that guide their thinking about the domain and help them integrate new knowledge. *Therefore, content instruction should be framed in terms of core ideas and transferable processes, not as discrete facts and skills.*

3. Different types of thinking, such as classification and categorization, inferential reasoning, analysis, synthesis, and metacognition, mediate and enhance learning. *Therefore, learning events should engage students in complex thinking to deepen and apply their learning.*

4. Learners reveal and demonstrate their understanding when they can apply, transfer, and adapt their learning to new and novel situations and problems. *Therefore, teachers should teach for transfer, and students should have multiple opportunities to apply their learning in meaningful and varied contexts.*

5. New learning is built on prior knowledge. Learners use their experiences and background knowledge to actively construct meaning about themselves and the world around them. *Therefore, students must be helped to actively connect new information and ideas to what they already know.*

6. Learning is social. *Therefore, teachers should provide opportunities for interactive learning in a supportive environment.*

7. Attitudes and values mediate learning by filtering experiences and perceptions. *Therefore, teachers should help students make their attitudes and values explicit and understand how they influence learning.*

8. Learning is nonlinear; it develops and deepens over time. *Therefore, students should be involved in revisiting core ideas and processes so as to develop deeper and more sophisticated learning over time.*

9. Feedback enhances learning and performance. *Therefore, ongoing assessments should provide learners with regular, timely, and user-friendly feedback, along with the opportunity to use it to practice, retry, rethink, and revise.*

10. Effectively accommodating a learner's prior knowledge, interests, and preferred styles of learning enhances learning. *Therefore, teachers should pre-assess to find out students' prior knowledge, learning preference, and interests. They should differentiate their instruction to address the significant differences they discover.*

that enables teachers to "check for understanding" and provide multiple opportunities for all students to learn key ideas and skills.

TIMSS Research

The Trends in International Mathematics and Science Study (TIMSS) tests mathematics and science achievement of students in 42 countries at three grade levels (4, 8, and 12) and is one of the most comprehensive and rigorous assessment of its kind ever undertaken. While the outcomes of TIMSS are well known—American students do not perform as well as students in most other industrialized countries (Martin, Mullis, Gregory, et. al., 2000)—the results of its less publicized curriculum and teaching studies offer explanatory insights. TIMSS researchers found that, in the United States, the mathematics and science curricula included too many topics and were highly unfocused (Schmidt, McKnight and Raizen, 1997), whereas, in high achieving countries, fewer topics taught each year, tied to more coherent, focused, developmental curricular offerings over time, enabled teachers and students to gradually build more complex understandings in mathematics, to delve deeply into subject matter, and to attain higher levels of achievement (Schmidt, Housing and Cogan, 2002; Schmidt, 2004).

Idea-Based, In-Depth Learning and Achievement Studies

Other research in mathematics and science education also suggests that curriculum and instructional practices that focus on core ideas and not on superficial facts and procedures lead to greater success and higher levels of achievement. For example, Weiss et. al. (2003) analyzed more than 300 lessons in a cross-section of mathematics and science classrooms in the United States, K-12. They found that a common characteristic of successful lessons was that students learned how to make sense of mathematical or scientific content by understanding the underlying concepts and then apply their learning to new situations.

In studying the difference between "breadth" learning (i.e. coverage) vs. "depth" learning (uncoverage), Schwartz, Sadler, Sonnert, and Tai (2008) found that students who had at least some in-depth learning experiences in high school science classes (one or more topics) also had higher achievement levels in college science classes, as compared to those whose sole experiences were "breadth" learning. Students who reported breadth coverage for all their major topics in biology had a significant disadvantage in college biology classes. The study also pointed to the typical "recall" type testing situations as the cause of much of the breadth teaching and learning.

In an article published in Education Week (2006), two big city districts, Boston and San Diego, that made significant improvements in their National Assessment of Educational Progress (NAEP) mathematics scores, credited two things for the better results – a focus on building students' conceptual math skills, and professional development for elementary and middle school mathematics teachers.

Authentic Pedagogy Study

In the mid-1990s, Newmann et al. (1996) conducted an ambitious study to determine whether schools with high levels of authentic pedagogy and performance in mathematics and social studies significantly increased achievement over those that measured at low levels. High levels were defined by a number of criteria, such as whether students were asked to explore connections and relationships so as to produce relatively complex understandings; to organize, synthesize, interpret or explain complex information; to elaborate on their understanding through extended writing; or to make connections to the world beyond the classroom (Newmann, Secada, and Wehlage, 1995). Similar students in classrooms with high and low levels of authentic pedagogy and performance were compared, and the results were striking: students in classes with high levels of authentic pedagogy and performance substantially increased achievement levels. Another significant finding was that the inequalities between high- and low-performing students were greatly decreased when normally low- performing students were in classrooms where teachers used authentic pedagogy and performance strategies and assessments.

Achievement Studies and Instructional Practice in Chicago Public Schools

Two major studies of factors influencing student achievement were conducted in Chicago public schools. In the first study, Smith, Lee, and Newmann (2001) focused on the link between different forms of instruction and learning in elementary schools. Test scores from more than 100,000 students in grades 2–8 and surveys from more than 5,000 teachers in 384 Chicago elementary schools were examined. The study compared teachers who used “interactive vs. non-interactive teaching methods” and their achievement results in reading and mathematics. Interactive instruction methods are described as follows:

> “Teachers … create situations in which students . . . ask questions, develop strategies for solving problems, and communicate with one another. . . . Students are often expected to explain their answers and discuss how they arrived at their conclusions. These teachers usually assess students’ mastery of knowledge through discussions, projects, or tests that demand explanation and extended writing…students discuss ideas and answers by talking, and sometimes arguing, with each other and with the teacher. Students work on applications or interpretations of the material to develop new or deeper understandings of a given topic. Such assignments may take several days to complete. Students in interactive classrooms are often encouraged to choose the questions or topics they wish to study within an instructional unit designed by the teacher. Different students may be working on different tasks during the same class period.” (p. 12).

The study found clear and consistent evidence that interactive teaching methods were correlated with higher levels of learning and achievement.

In a related study, Newmann, Bryk, and Nagaoka (2001) examined the relationship of the nature of classroom assignments to standardized test performance. Researchers in Chicago systematically collected and analyzed classroom writing and mathematics assignments in grades 3, 6, and 8 from randomly selected and control schools over the course of three years. Assignments were rated according to the degree to which they required “authentic” intellectual work, which the researchers described as follows:

> “Authentic intellectual work involves original application of knowledge and skills, rather than just routine use of facts and procedures. It also entails disciplined inquiry into the details of a particular problem and results in a product or presentation that has meaning or value beyond success in school. We summarize these distinctive characteristics of authentic intellectual work as construction of knowledge, through the use of disciplined inquiry, to produce discourse, products, or performances that have value beyond school.” (pp. 14-15)

The study concluded that students who received assignments requiring more challenging intellectual work also achieved greater than average gains on the Iowa Tests of Basic Skills in reading and mathematics, and demonstrated higher performance in reading, mathematics, and writing on the Illinois Goals Assessment Program.

High Schools That Work (HSTW)

High Schools That Work (Bottoms, Presson and Johnson, 1992) is a nationally recognized program for integrating academic and vocational education, and grounds its practices in four principles that support meaning and understanding based teaching and learning:

1. **A challenging curriculum** that "equips students to think analytically, to reason, to judge, and to balance opposing points of view." Such a curriculum "encourages students to …use academic and technical content and processes to complete tasks typical of those found in the workplace and the community; [and] construct new meanings and understandings from information and ideas."
2. **Teaching for understanding** "creates challenging situations in which students test their knowledge by solving problems, building products, and giving performances or writing reports that synthesize thorough analysis of a topic, a concept, or an idea."
3. **Teaching in a meaningful context** "provides a way to apply academic learning to important 'real-world' problems" and helps students "see meaning and purpose in their studies."
4. **Setting clear performance standards** so that assessments of learning are "based on clearly stated standards that require students to demonstrate their understanding of new knowledge and skills." (Bottoms & Sharpe, 1996, pp. 20-24)

Research conducted by the National Center for Research in Vocational Education (2000) has confirmed the effectiveness of high school programs that embody these principles. For example, one study over a two-year period found that High Schools That Work sites significantly increased the percentages of students in their senior classes who met the HSTW achievement goals in mathematics, science, and reading and the percentages of students in their senior classes who completed the HSTW-recommended program of study" (Frome, 2001).

Research on Mathematics Curricula

In an exhaustive analysis of mathematics instruction in Japan, Germany, and the United States, Stigler and Hiebert (1999) present striking evidence of the benefits of teaching for meaning and understanding, deepening learning, and increasing thoughtfulness in optimizing performance. For example, in Japan, a high achieving country, mathematics teachers state that their primary aim is to develop conceptual understanding in their students. They cover less ground in terms of discrete topics, skills, or pages in a textbook, but they emphasize problem-based learning, in which rules and theorems are derived and explained by the students, thus leading to deeper understanding. The TIMSS analysis of mathematics education data from seven countries also indicates that all high achieving countries use a percentage of their mathematics problems to help students explore concepts and make connections, while United States teachers tend to emphasize "algorithmic plug in" of procedures, instead if genuine reasoning and problem solving (Hiebert, Gallimore, Garnier, et. al, 2003, pp. 203-204; Stigler and Hiebert, 2004, pp. 15-16)

In 1989, the National Council of Teachers of Mathematics (NCTM) issued a set of standards for mathematics that reduced the emphasis on rote learning of mathematical formulas and procedures and increased emphasis on conceptual understanding of mathematics. Since then, a number of new curriculum materials based on this approach, focusing on understanding underlying mathematical concepts, complex problem solving, student explanation of their work, and authentic performance and assessment have been developed. Most have been implemented within the last dozen years.

Senk and Thompson (2003) summarized the results of thirteen studies of mathematics curricula that follow the NCTM approach. While much of this research was still in the preliminary stages, the results are suggestive. For example, children who used a program called *Investigations* in the elementary school[4] "performed better than their counterparts from other curricula with respect to word problems, more complex calculations embedded in word problems, and problems that involved explaining how an operation worked" (p. 127). Longitudinal data from middle schools show that students using understanding-based mathematics curricula demonstrate superior performance in both non-routine problem solving and mathematical skills (Senk & Thompson, 2003, p. 288-289). Finally, a series of studies using high school mathematics reform programs "…offer overwhelming evidence that the reform curriculum can have a positive impact on high school mathematics achievement. It is not that students in these curricula learn traditional content better but that they develop other skills and understandings while not falling behind on traditional content. These evaluations present more solid scientific evidence than has ever before been available about the impact of curriculum materials" (Senk & Thompson, 2003, p. 468).

Research on Technology

Wenglinsky (1998) conducted a study of the relationship between the various uses of technology and achievement in mathematics. Achievement data on the 1996 National Assessment of Educational Progress (NAEP) were analyzed and correlated with survey data including the frequency of computer use for mathematics and the kinds of instructional uses of computers in the schools. After factoring out variables such as socio-economic status, class size and teacher qualifications, Wenglinsky found significant achievement relationships in the eighth grade between NAEP test scores and the use of technology that focused on mathematical projects, problems and simulations that promoted application of knowledge and higher order thinking. Surprisingly, using computers in the eighth grade for drill and practice was negatively related to student achievement.

Achievement Differences Based on Student Perceptions of Teacher Effectiveness

The Bill and Melinda Gates Foundation (2010) supported a study of student perceptions of teacher effectiveness and its relation to student achievement gains. The initial results indicate that there is a strong relationship between teachers helping students understand math concepts, teachers helping students to demonstrate reading comprehension through writing (application of ideas), and levels of achievement on standardized tests. In other words, there were significant achievement differences between classrooms in which teachers helped students understand math concepts versus those that did not, or in classrooms in which students demonstrated their reading comprehension through writing versus classrooms where students did not. Another important initial result indicated that, in classrooms in which students reported teachers focused on test preparation, test results were not likely to be at a high level. "On the contrary, the type of teaching that leads to gains on the state tests corresponds with better performance on cognitively challenging tasks and tasks that require deeper conceptual understanding, such as writing" (p. 5).

Research on Instructional Practices

Numerous studies of instruction have confirmed the effectiveness of specific instructional strategies for improving student achievement, many of which support 21st century outcomes and skill learning. For example, Stone (1983) used a meta-analysis technique to examine 112 studies on the use of advance organizers to help students organize and connect information and ideas. Overall, advance organizers were shown to be associated with increased learning and retention of material at all grade and ability levels, but lower-ability students tended to profit the most. A meta-analysis of 18 experiments by Redfield and Rousseau (1981) concluded that the predominant use of higher-level questions during instruction yielded positive gains on tests of factual recall and application of thinking skills. Andre (1979) describes a study that investigated the effects of having students respond to higher-order questions that were inserted every few paragraphs in a text. The researchers concluded that such a procedure facilitates better textbook learning than do fact question inserts. Pressley and colleagues (1992) showed that asking students for explanatory responses to higher-level questions *prior* to instruction activates prior knowledge and focuses attention, resulting in better learning.

A considerable body of research supports the use of meaning-based, reflective reading strategies to improve reading. For example E.D. Hirsch, Jr. (2003) demonstrates that using strategies to systematically build "word and world knowledge" -- student understanding of what language refers to – is the key to bridging the reading gap between socioeconomic groups and solving the fourth grade slump problem. In the same issue of American Educator[5], researchers and educators suggest specific types of strategies, such as reading and discussing ideas and vocabulary instruction, in order to help students improve reading comprehension and fluency.

Marzano, Pickering, and Pollock (2001) summarized and analyzed multiple studies in order to show that a number of types of instructional strategies significantly affect student achievement. Several strategies found to be highly effective explicitly assist students in making connections, conceptualizing knowledge, and explaining and applying knowledge and ideas to new situations:

1. Identifying similarities and differences;
2. Using “nonlinguistic representations”—primarily graphic organizers, models, mental pictures, artistic expression, and kinesthetic activity;
3. Generating and testing hypotheses through systems analysis, problem solving, historical investigation, invention, and experimental inquiry; and
4. Asking students to explain their thinking.

Unfortunately, much classroom practice in the United States today ignores this key research on effective instruction and incorporates more traditional instructional methods that do not prepare students for a 21st century world. For example, a large-scale study by Pianta (2007) revealed that much of elementary school instruction revolves around learning discrete skills taught through specific lessons and/or worksheets. In his study, 2,500 science classrooms in 400 school districts were observed across the U.S. Fifth graders spend 91 percent of their time listening to the teacher or working alone, usually on low-level worksheets. Three out of four classrooms are “dull, bleak” places, the researchers report, devoid of any emphasis on critical reasoning or problem-solving skills.

Project Based Learning Research

Several studies suggest that project based learning approaches have a significant effect on learning and achievement. Project Based Learning incorporates the learning of a number of key Era 3 learning goals, and enables learners to develop significant 21st century skills. According to the Buck Institute for Education (BIE), the characteristics of effective project based learning include the following -- Projects:

•**Are organized around an open-ended Driving Question or Challenge.** These focus students' work and deepen their learning by centering on significant issues, debates, questions and/or problems.
•**Create a need to know essential content and skills.** Typical projects (and most instruction) begin by presenting students with knowledge and concepts and then, once learned, give them the opportunity to apply them. PBL begins with the vision of an end product or presentation that requires learning specific knowledge and concepts, thus creating a context and reason to learn and understand the information and concepts.
•**Require inquiry to learn and/or create something new.** Not all learning has to be based on inquiry, but some should. And this inquiry should lead students to construct something new – an idea, an interpretation, a new way of displaying what they have learned.
•**Require critical thinking, problem solving, collaboration, and various forms of communication.** Students need to do much more than remember information—they need to use higher-order thinking skills. They also have to learn to work as a team and contribute to a group effort. They must listen to others and make their own ideas clear when speaking, be able to read a

variety of material, write or otherwise express themselves in various modes, and make effective presentations. These skills, competencies and habits of mind are often known as "21st Century Skills".
•**Allow some degree of student voice and choice.** Students learn to work independently and take responsibility when they are asked to make choices. The opportunity to make choices, and to express their learning in their own voice, also helps to increase students' educational engagement.
•**Incorporate feedback and revision.** Students use peer critique to improve their work to create higher quality products.
•**Result in a publicly presented product or performance.** What you know is demonstrated by what you do, and what you do must be open to public scrutiny and critique.

Boaler's (1998) study of two school's mathematics programs in England strongly supports the power of project-based instruction. The two schools were similar in terms of socio-economic status, and previously had similar mathematics achievement levels. One school's program incorporated a teacher-directed, didactic format, with whole class instruction, the use of textbooks, tracking of students, and the frequent use of traditional tests. At the other school, students worked on open-ended mathematics projects and problems in heterogeneous groups, with little use of textbooks or tests.

In interviews with students over the three years, students at the traditional school found the work "boring and tedious". They also thought of mathematics as the ability to "remember and use rules". Students at the project-based school thought of mathematics as a "dynamic, flexible subject that involved exploration and thought", and had more positive attitudes about mathematics than students at the traditional school. After three years, students at the project-based school performed as well or better than students at the traditional school at items that required rote knowledge, but three times as many students at the project based school attained the highest possible grade in mathematics on the national exam. Overall, significantly more students at the project-based school passed their national exams administered in year three of the study than those at the traditional school.

Classroom Implications

A significant research base exists that supports what we call an "Era 3, 21st Century education" -- a meaningful, understanding based curricular and instructional program in which every subject is focused around core understandings and critical 21st century skills and habits of mind. Cognitive psychology research indicates that student learning is enhanced when students are able to explore, organize, connect, process, and apply information and ideas. Student achievement is strengthened when the curriculum is focused, coherent, developmental, and allows for in-depth, understanding based learning; when instruction focuses on the underlying concepts and ideas to be learned rather than on learning and memorizing discrete bits of information; when students are engaged in the learning process through the use of authentic pedagogy and academic performance tasks that enable them to apply their learning; when they ask questions and develop strategies for problem solving. Research also supports the idea that interactive, engaging instructional strategies, such as graphic organizers, higher order questioning, generating and testing hypotheses, asking students to explain their thinking, and the use of specific reading strategies that enlarge vocabulary and student conceptual frameworks, foster the learning of key ideas and skills make a significant difference in learning and achievement. Project based instruction has also been shown to have a significant effect on achieving key 21st century learning goals.

Much of this research goes against the prevailing emphasis on "covering" factual knowledge and practicing low-level procedures and "test-prep" strategies in an attempt to improve standardized test scores. The research cited here suggests that, if we want to prepare students for an Era 3 world, increase achievement levels, enable students to apply what they have learned, and prepare them for college and careers, we need a greater focus on helping students develop a deep understanding of content, learning and using critical 21st century skills, and applying learning to new, novel and authentic situations.

Based on this research, we hope that more schools and districts will view Era 3, 21st century learning goals and principles as a long term, significant framework for educating students for today's and tomorrow's world.

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Endnotes

[1]This article is adapted, revised and updated from a previous version: McTighe and Seif, *Teaching for Meaning and Understanding: A Summary of Underlying Theory and Research,* published in Pennsylvania Educational Leadership journal, Fall, 2004, pp. 6-14.

[2] Era 3 is the current era that encompasses the information and technological age. Era 1 encompassed the agricultural age and Era 2 the industrial age. Each age has very different educational needs. For a further overview, see Seif, *Educational Excellence in an Era 3 World,* unpublished paper available on the website era3learning.org.

[3] This synthesis of learning research originally appeared in McTighe and Seif, *An Implementation Framework to Support 21st Century Skills* (2010) in Bellanca, James, and Brandt, Ron, editors, *21st Century Skills: Rethinking How Students Learn,* Bloomington, IN: Solution Tree Press, Chapter 7, p. 153

[4] *Investigations* is a K-5 mathematics education program developed by TERC, funded in part by the National Science Foundation, and published by Pearson Scott Foresman.

[5] See articles and research by Hart and Risley, Chall and Jacobs, Stahl, Biemiller, Walsh, Duke, et.al., and Beck, et. al. in American Educator, Spring 2003