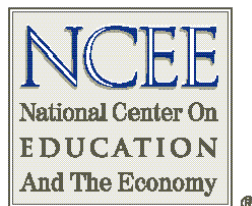


**Rethinking and Redesigning Curriculum,
Instruction and Assessment:
What Contemporary Research and Theory Suggests**

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**A Paper Commissioned by the
National Center on Education and the Economy for the
*New Commission on the Skills of the American Workforce***

November 2006



Rethinking and Redesigning Curriculum, Instruction and Assessment: What Contemporary Research and Theory Suggests

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The “New” Commission Report offers a bold approach to addressing issues regarding the knowledge, skills and competitiveness of America’s workforce in a rapidly changing international marketplace. Among its many recommendations for improving how we currently educate our youth, as well as re-educate adults in the workforce, are the need for dramatic changes in the processes of teaching, learning, and assessment leading to substantial gains in the overall achievement outcomes of the system. In many respects, the current Report builds on ideas offered in the first Commission Report released over 15 years ago. That Report was a stimulus for the standards and accountability movement in America, a movement that has led to many changes in American education. Some of those changes have proven useful such as the attempt to develop serious content standards for multiple areas of the curriculum. But some have proven not very helpful, such as the proliferation of accountability-oriented assessments that serve to undermine attainment of those very same achievement standards.

This brief essay attempts to provide an argument in support of some of the critical changes advocated in the “New” Report. The argument is based on an accumulating body of theory and research on learning and knowing that has profound implications for how to transact key aspects of the educational process. Much of what is presented is consonant with ideas and conclusions reached in a number of National Research Council Reports on learning, instruction, and assessment issued over the last decade, starting with the Science Standards in 1996 (NRC, 1996). Many of the most pertinent NRC reports have appeared within the last 6 years (e.g., Bransford, Brown, Cocking, Donovan & Pellegrino, 2000; Donovan & Bransford, 2005; Donovan & Pellegrino, 2004; Kilpatrick, Swafford & Findell, 2001; NRC, 2002, 2003; Pellegrino, Chudowsky & Glaser, 2001; Wilson & Bertenthal, 2005).

Three major points need to be made in support of key recommendations contained in the New Commission Report.

First, we know a great deal more about the nature of competence and the development of expertise in multiple areas of the curriculum including mathematics, science, literature, history, and the arts. However, very little of that knowledge has been used to date to shape the nature of our curricular goals, our instructional processes, or our modes of assessment. Standards alone are not enough – we must translate those standards into details about the nature of knowledge and the development of understanding that can guide three key aspects of the educational process – curriculum, instruction, and assessment.

Second, the type of expertise advocated in the Commission Report goes well beyond the development of basic skills and “routine expertise” and represents instead the levels of knowledge and understanding that can support transfer to new problems, creativity

and innovation, something that we now recognize as “adaptive expertise.” The latter should be our target if we are to succeed in the ways advocated by the Report. Furthermore, given that teaching requires a unique form of expertise above and beyond knowledge of a given discipline, we must develop teachers who themselves have adaptive expertise in the domain of daily classroom instruction.

Third, our assessment system is seriously flawed and broken. Given the amount that we currently spend on the large-scale assessment of academic achievement, we get very little in the way of positive return on investment. Many believe the return is actually negative with respect to valued educational outcomes. Unless our approach to assessment is changed substantially so that it can support processes of teaching and learning focused on deep learning and understanding, there is little hope of attaining the levels of achievement advocated in the New Commission Report. Thus, the dollars we now spend on assessment should be reinvested in more targeted and efficacious assessment approaches tied to important curricular goals. These assessments should be meaningful to the individuals assessed and have real value in determining their readiness to move on in the educational system.

In the remainder of this essay, information is provided that supports each of these three major points. At the core of the argument is the idea that knowledge about the nature of learning and understanding is key to accomplishing our educational goals. Such knowledge should serve as the cornerstone for designing an educational process directed towards attaining the goals identified in the New Commission Report. To start that discussion, however, we need to briefly consider three interacting elements of educational practice, including the disjunctures that often occur among them, and what role an understanding of learning and knowing can play in achieving synergy of the type argued for in the New Commission Report rather than the chaos that now exists.

The Curriculum-Instruction-Assessment Triad

Whether we recognize it or not, three things are central and operative in the American educational enterprise – curriculum, instruction, and assessment. The three elements of this triad are linked, although the nature of their linkages and reciprocal influence is often far less explicit than it should be. Furthermore, the separate pairs of connections are often inconsistent which leads to overall incoherence in the educational enterprise.

Curriculum consists of the knowledge and skills in subject matter areas that teachers teach and students are supposed to learn. The curriculum generally consists of a scope or breadth of content in a given subject area and a sequence for learning. Standards in mathematics and science typically outline the goals of learning, whereas curriculum sets forth the more specific means to be used to achieve those ends. *Instruction* refers to methods of teaching as well as the learning activities used to help students master the content and objectives specified by a curriculum. Instruction encompasses the activities of both teachers and students. It can be carried out by a variety of methods, sequences of activities, and topic orders. *Assessment* is the means used to measure the outcomes of education and the achievement of students with regard to important competencies. Assessment may include both formal methods, such as large-scale state or national assessments, or less formal classroom-based procedures, such as quizzes, class projects, and teacher questioning.

A precept of educational practice is the need for alignment among curriculum, instruction, and assessment. Alignment, in this sense, means that the three functions are directed toward the same ends and reinforce each other rather than working at cross-purposes. Ideally, an assessment should measure what students are actually being taught, and what is actually being taught should parallel the curriculum one wants students to master. If any of the functions is not well synchronized with the others, it will disrupt the balance and skew the educational process. Assessment results will be misleading, or instruction will be ineffective. Alignment is difficult to achieve, however. Often what is lacking is a central theory about the nature of learning and knowing in a given domain of knowledge and expertise around which the three functions can be coordinated.

Most current approaches to curriculum, instruction, and assessment are based on theories and models that have not kept pace with modern knowledge of how people learn. They have been designed on the basis of implicit and highly limited conceptions of learning. Those conceptions tend to be fragmented, outdated, and poorly delineated for domains of subject-matter knowledge. Alignment among curriculum, instruction, and assessment could be better achieved if all three are derived from a scientifically credible and shared knowledge base about cognition and learning in the subject matter domains. The model of learning would provide the central bonding principle, serving as a nucleus around which the three functions would revolve. Without such a central core, and under pressure to prepare students for high-stakes accountability tests, teachers often feel compelled to move back and forth between instruction and external assessment and teach directly to the items on a state test. This approach has consistently been shown to result in an undesirable narrowing of the curriculum and a limiting of learning outcomes. Such problems can be ameliorated if, instead, decisions about both instruction and assessment are guided by a model of learning in the domain that represents the best available scientific understanding of how people learn. This brings us to a brief consideration of what we actually know about the nature of learning and knowing and how it relates to some of the basic recommendations of the New Commission Report.

Some Important Principles About Learning and Understanding

While there are many important findings about learning and understanding that bear on the design of curriculum, instruction, and assessment, three are highlighted here. Each has a solid research base to support it, has strong implications for how we teach, and helps us think about ways in which technology assists in the design and delivery of effective learning environments.

The first important principle about how people learn is that students come to the classroom with preconceptions about how the world works which include beliefs and prior knowledge acquired through various experiences. In many cases, the preconceptions include faulty mental models about concepts and phenomena. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom. Research on early learning suggests that the process of making sense of the world begins at a very young age. Children begin in preschool years to develop sophisticated understandings (whether accurate or not) of

the phenomena around them. Those initial understandings can have a powerful effect on the integration of new concepts and information. Sometimes those understandings are accurate, providing a foundation for building new knowledge. But sometimes they are incomplete and/or inaccurate. In science, students often have misconceptions of physical properties that cannot be easily observed. In humanities, their preconceptions often include stereotypes or simplifications, as when history is understood as a struggle between good guys and bad guys. A critical feature of effective teaching is that it elicits from students their preexisting understanding of the subject matter to be taught and provides opportunities to build on, or challenge, the initial understanding. The more we can do at an early age to establish a sound conceptual foundation in areas such as number, literacy, and scientific understanding, the greater will be the progress of students in mastering content at deep conceptual levels during the schooling process. Thus, the recommendation for investment in universal, high quality early childhood education is especially critical and something that is long overdue.

It is also worth noting that drawing out and working with existing understandings is important for learners of all ages not just young children. Numerous research studies demonstrate the persistence of preexisting understandings even after a new model has been taught that contradicts the naïve understanding. Students at a variety of ages persist in their beliefs that seasons are caused by the earth's distance from the sun rather than by the tilt of the earth, or that an object that had been tossed in the air has both the force of gravity and the force of the hand that tossed it acting on it, despite training to the contrary. For the scientific understanding to replace the naïve understanding, students must reveal the latter and have the opportunity to see where it falls short.

The second important principle about how people learn is that to develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. This principle emerges from research that compares the performance of experts and novices, and from research on learning and transfer. Experts, regardless of the field, always draw on a richly structured information base; they are not just “good thinkers” or “smart people.” The ability to plan a task, to notice patterns, to generate reasonable arguments and explanations, and to draw analogies to other problems, are all more closely intertwined with factual knowledge than was once believed.

But knowledge of a large set of disconnected facts is not sufficient. To develop competence and expertise in an area of inquiry, students must have opportunities to learn with understanding rather than memorizing factual content. Key to expertise is a deep understanding of subject matter that transforms factual information into “usable knowledge.” A pronounced difference between experts and novices is that experts' command of concepts shapes their understanding of new information: it allows them to see patterns, relationships, or discrepancies that are not apparent to novices. They do not necessarily have better overall memories than other people. But their conceptual understanding allows them to extract a level of meaning from information that is not apparent to novices, and this helps them select and remember relevant information. Experts are also able to fluently access relevant knowledge because their understanding

of subject matter allows them to quickly identify what is relevant. Hence, their attention is not overtaxed by complex events.

A key finding in the learning and transfer literature is that organizing information into a conceptual framework allows for greater “transfer”; that is, it allows the student to apply what was learned in new situations and to learn related information more quickly. The student who has learned geographical information for the Americas in a conceptual framework approaches the task of learning the geography of another part of the globe with questions, ideas, and expectations that help guide acquisition of the new information. Understanding the geographical importance of the Mississippi River sets the stage for the student’s understanding of the geographical importance of the Nile, or the Rhine or the Yangtze. And as concepts are reinforced, the student will transfer learning beyond the classroom, observing and inquiring about the geographic features of a visited city that help explain its location and size. The New Commission Report emphasizes the creative and inventive aspects of knowledge development and use. Attainment of such objectives requires curriculum and instruction to be focused on the conceptual organization of knowledge and the teasing out of “big ideas” in a discipline from the earliest stages of learning onward rather than an undue emphasis on rote knowledge of facts and procedures.

A third critical idea about how people learn is that a “metacognitive” approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them. In research with experts who were asked to verbalize their thinking as they worked, it was revealed that they monitored their own understanding carefully, making note of when additional information was required for understanding, whether new information was consistent with what they already knew, and what analogies could be drawn that would advance their understanding. These metacognitive monitoring activities are an important component of what is called adaptive expertise.

Because metacognition often takes the form of an internal conversation, it can easily be assumed that individuals will develop the internal dialogue on their own. Yet many of the strategies we use for thinking reflect cultural norms and methods of inquiry. Research has demonstrated that children can be taught these strategies, including the ability to predict outcomes, explain to oneself in order to improve understanding, note failures to comprehend, activate background knowledge, plan ahead, and apportion time and memory. The teaching of metacognitive activities must be incorporated into the subject matter that students are learning. These strategies are not generic across subjects, and attempts to teach them as generic can lead to failure to transfer. Teaching metacognitive strategies in context has been shown to improve understanding in physics, written composition, and heuristic methods for mathematical problem solving. And metacognitive practices have been shown to increase the degree to which students transfer to new settings and events.

While the above three principles, and others, are now well understood and have been shown to be operative in multiple areas of the curriculum it is an unfortunate reality that little of this knowledge has found its way into contemporary curricular materials and instructional practices. Included among the latter are problem-based and project-based approaches to instruction of the type seen in other countries and in certain areas

of advanced education including medicine, law, and engineering. Within these approaches, students are challenged to think deeply about content and apply concepts and principles to the solution of interesting and relevant challenges within a domain. This is far more than simply “hands-on” and fun activities. Identifying good problems and the effective scaffolding of problem-based learning is quite demanding from an instructional design perspective.

A major impediment to progress in America’s educational system is that the diverse approaches to instruction that are needed to support the processes of complex learning and knowledge development are quite demanding to manage and orchestrate. They require much more disciplinary knowledge on the part of teachers as well as instructional flexibility and adaptive expertise than has typically been the case in America’s classrooms. There are, of course, exceptions to such a generalization. Nevertheless, it has proven difficult to achieve on any large scale the conditions of learning that are needed to support the development of the types of competence and expertise emphasized by the New Commission Report. One issue is whether the current teaching force is capable of attaining the levels of adaptive expertise needed and providing the appropriate levels of support for student learning. America has many fine and dedicated teachers but we also have a very inefficient system in which we lose many of the brightest and most talented teachers within a short period of time. Not only do we drive good teachers out of the system but we have to train many more than we otherwise should thereby reducing the effectiveness of the initial training that we do provide. If other professions such as medicine operated in the same inefficient manner we would be in major trouble there as well. There is no simple solution to the teacher workforce problem but we must recognize the complexity and demands associated with excellent teaching. The New Commission Report has made a number of important suggestions about what needs to be done to change the current teacher workforce realities through the use of incentives as well as rigorous selection and training processes.

There is, however, another critical impediment that must be acknowledged and changed. It is a factor that often drives creativity right out of the teaching arena and drives talented persons away from the teaching profession. Whether we like to admit it or not, America’s reliance on the use of highly limiting, external accountability assessments of academic achievement is having a negative impact on attaining our lofty objectives for the educational system. And it is to that issue that we now turn.

The Conflict Between Rising Expectations and Contemporary Assessment Practices

It is somewhat ironic that in the context of rising expectations about what all students should learn—and, by implication, what they should be assessed on—we have moved in the opposite direction with respect to the types of assessments that now drive the educational system. Under the No Child Left Behind legislation, states have been driven to put in place assessment systems that seriously undermine high achievement standards and quality instructional practices. In addition to the many conceptual and operational weaknesses of these assessments as indicated below, there is little awareness on the part of the public concerning the tremendous amount of money that is being spent by each state separately on designing and administering these tests as well as by the federal government in monitoring the separate states assessments and

enforcing the provisions of the NCLB legislation. These are dollars that would be far better spent on quality assessment that was much more closely linked to important curricular and instructional goals such as those outlined in the New Commission Report.

At least four sets of concerns exist about the quality and efficacy of the current assessment systems that many states have produced in their attempt to comply with the NCLB regulations:

- **Effectiveness of measurement.** Do the most widely used assessments effectively capture the complex knowledge and skills emphasized in contemporary standards and deemed essential for success in the information-based economy? Probably not. Limits on the kinds of competencies currently being assessed also raise questions about the inferences one can therefore draw from test results. If scores go up on a test that measures a relatively narrow range of knowledge and skills, does that mean student learning has improved, or has instruction simply adapted to a constrained set of outcomes? If there is explicit "teaching to the test," at what cost do such gains in test scores accrue relative to acquiring other aspects of knowledge and skill that are valued in today's society? This is a point of considerable controversy with regard to the so-called "miracle in Texas" but also for the periodic ups and downs in state assessment results more generally.
- **Utility for improving teaching and learning.** How useful are current assessments for improving teaching and learning -- the ultimate goal of education reforms? Not very. Most current large-scale tests provide very limited information that teachers and educational administrators can use to identify why students do not perform well, or to modify the conditions of instruction in ways likely to improve student achievement. The most widely used state and district assessments provide only general information about where a student stands relative to peers or whether the student has performed poorly or well in certain domains (for example, that the student performs "below basic" in mathematics). Such tests do not reveal whether students are using misguided strategies to solve problems or fail to understand key concepts within the subject matter being tested. They do not show whether a student is advancing toward competence or is stuck at a partial understanding of a topic that could seriously impede future learning. In short, many current assessments do not provide strong clues as to the types of educational interventions that would improve learners' performance, or even provide information on precisely where the students' strengths and weaknesses lie. Nor is information provided in a timely manner.
- **"Snapshots" versus progression over time.** Can we tell how much a student has progressed in a year? Not really. Most assessments provide "snapshots" of achievement at particular points in time, but they do not capture the progression of students' conceptual understanding over time, which is at the heart of learning. This limitation exists largely because most current modes of assessment lack an underlying theoretical framework of how student understanding in a content area develops over the course of instruction, and predominant measurement methods are not designed to capture such growth.

- **Fairness and equity.** Are tests fair and equitable? Perhaps not. Much attention is given to the issue of test bias -- whether differences occur in the performance of various groups for reasons that are irrelevant to the competency the test is intended to measure. Standardized-test items are subjected to judgmental and technical reviews to monitor for this kind of bias. However, the use of assessments for high-stakes decisions raises additional questions about fairness. If the assessments are not aligned with what students are being taught, it is not fair to base promotion or rewards on the results, especially if less advantaged students are harmed disproportionately by the outcome.

If current assessments do not effectively measure the impact of instruction or if they fail to capture important skills and knowledge, how can educators interpret and address gaps in student achievement? One of the main goals of proposed reforms is to improve learning for all students, but especially low-achieving students. If this goal is to be accomplished, assessment must give students, teachers, administrators and other stakeholders information they can use to improve learning and inform instructional decisions for individuals and groups, especially those not performing at high levels.

One of the most important things to recognize is that assessments need to be designed to satisfy specific purposes (e.g., formative, summative, or program evaluation) and that different assessment purposes demand different assessment designs. The current accountability tests developed by states to comply with NCLB are ostensibly designed to fulfill multiple purposes. However, in attempting to do so most states have created sub-optimal designs. If the goal is to monitor the overall status of educational achievement then assessment approaches of the type used in the National Assessment of Educational Progress are far better suited to this purpose especially with respect to valued curricular outcomes. If, however, the goal is to monitor the attainment of individual students with respect to specific curricular goals and standards then one needs assessments designed to meet that purpose. In this regard, the recommendation of the New Commission Report for periodic, standards-based exams in specific curricular areas is a far better investment of resources than the mass standardized testing approach that now dominates the educational landscape across K-12. Not only would students and teachers have a clearer sense of the content and criteria on which performance would be evaluated but the assessments would serve the needs of the individual and they would be motivated to perform well as opposed to the current situation of meeting the needs of a bureaucracy and not the individual tested. In addition to developing high quality, standards-based exams in critical instructional areas, considerably more investment is needed in ways to make the assessment process more supportive of teaching and learning through effective formative assessment materials and practices. In the material that follows, consideration is given to what it might take to build a far better system of assessments that would help meet the goals articulated in the New Commission Report.

Outmoded Theories and Underutilized Technologies

Whether we realize it or not, every educational assessment, whether used in the classroom or large-scale policy context, is based on a set of scientific principles and philosophical assumptions. First, every assessment is grounded in a conception or theory about how people learn, what people know, and how knowledge and

understanding progress over time. Second, each assessment embodies certain assumptions about which kinds of observations, or tasks, are most likely to elicit demonstrations of important knowledge and skills from students. Third, every assessment is premised on certain assumptions about how best to interpret the evidence from the observations in order to make meaningful inferences about what students know and can do.

Current assessment systems are the cumulative product of various prior theories of learning and methods of measurement. Although some of these foundations are still useful for certain functions of testing, major change is needed. The most common kinds of educational tests do a reasonable job with certain limited functions of testing, such as measuring knowledge of basic facts and procedures and producing overall estimates of proficiency for restricted parts of the curriculum. But both their strengths and limitations are a product of their adherence to theories of learning and measurement that are outmoded and fail to capture the breadth and richness of knowledge and competence. The limitations of these theories also compromise the usefulness of the assessments. Assessment systems need to evolve to keep pace with developments in the sciences of learning and measurement if we are to achieve the learning goals embedded in current and future standards.

Rethinking the Foundations of Assessment: The Merger of Cognition, Measurement and Technology

As described above, several decades of research in the learning sciences have advanced our knowledge about how children develop understanding in areas of the curriculum, how people reason and build structures of knowledge in academic subject areas, which thinking processes are associated with competent performance, and how knowledge is shaped by social context. As noted earlier, studies of expert-novice differences in subject domains have illuminated many critical features of proficiency that should be the targets for assessment. Experts in a subject domain not only “know a lot” -- more importantly they organize knowledge into schemas that support the rapid retrieval and application of such knowledge. Experts also use metacognitive strategies -- ways of guiding one’s thinking -- for monitoring understanding during problem-solving and for performing self-correction.

These and many other findings on how people learn and the differences in what novices and experts know suggest directions for revamping assessment practices to move beyond a focus on component skills and discrete bits of knowledge. Assessment should encompass the more complex aspects of student achievement. To aid learning, we need to have access to better information about students’ levels of understanding, their thinking strategies and the nature of their misunderstandings. This also suggests the need for a serious investment in high quality assessments that are domain specific and that take into account the richness of knowledge that we associate with high levels of competence in a domain. These could well be the types of periodic exams recommended in the New Commission Report. It will, however, take a serious investment to design and validate such assessments but the investment should be well worth it in terms of utility within the educational system. It also makes sense for this to function as a collaborative activity among states rather than a series of separate investments by individual states in much inferior assessment products.

During the last few decades significant developments have also accrued in measurement methods and theory. A wide array of statistical measurement methods are currently available to support the rigor we want in testing while simultaneously enabling the kinds of inferences about student knowledge that cognitive research suggests are important to pursue when assessing student achievement. In particular, it is now possible to characterize students in terms of multiple aspects of proficiency, rather than a single score; chart students' progress over time, instead of simply measuring performance at a particular point in time; deal with multiple paths or alternative patterns of valued performance; model, monitor and improve judgments based on informed evaluations; and report performance not only at the level of students, but also at the levels of groups, classes, schools and states. Nonetheless, many of the newer models and methods are not widely used because they are not easily understood or packaged in accessible ways for those without a strong technical background.

Technology offers the possibility of addressing this shortcoming. For instance, by building statistical models into technology-based learning environments for use in classrooms, teachers can assign more complex tasks, capture and replay students' performances, share exemplars of competent performance, and in the process gain critical information about student competence. Without question, computer and telecommunications technologies are making it possible to create powerful learning environments and simultaneously assess what students are learning at very fine levels of detail, with vivid simulations of real-world situations, and in ways that are tightly integrated with instruction.

Research has already shown that assessments that inform teachers about the nature of student learning can help them provide better feedback to students, which in turn can significantly enhance learning. Many of the most effective examples of the use of assessment to inform learning and instruction in the classroom rely on technology-based task presentation and information management systems.

If well-designed and used properly, assessments based on contemporary scientific knowledge could also promote more equitable opportunity to learn by providing better-quality information about the impact of educational interventions on children. More informative classroom assessments could result in earlier identification of learning problems and intervention for children at risk of failure, rather than waiting for results from large-scale assessments to signal problems. Students with disabilities could also benefit from this approach. At the same time, it is necessary for educators and researchers to continuously monitor the effects of their practices to ensure that the new assessments do not exacerbate existing inequalities.

Assessments based on contemporary theories and data on how competence develops across grade levels in a curriculum domain could also provide more valid measures of growth and the value added by teachers and schools. Such assessments could also enhance community dialogue about goals for student learning and important indicators of achievement at various grade levels and in different subject areas. Comparisons based on attainment of worthwhile learning goals, rather than normative descriptions of how students perform, could enhance the public's understanding of educational

quality. New forms of assessment could also help provide descriptive and accurate information about the nature of achievement in a subject area and patterns of students' strengths and weaknesses that would be more useful than existing data for guiding policy decisions and reform efforts.

It is no surprise, then, that collective advances in the study of thinking and learning, in the field of measurement, and in the deployment of powerful technologies for learning have stimulated many people to think in new ways about educational futures. New information technologies provide substantial opportunities to advance the design and use of assessments based on a merger of contemporary scientific knowledge of cognition and measurement. Focus is needed on ways to bring together the knowledge of how students learn, what they know and what is therefore worth assessing, with knowledge of how to do this with technical rigor, and ways to harness technology to make the merger feasible. Several intriguing implications arise from projecting what could happen from the coupling of advances in cognition, measurement and technology.

Visions of the Future

Within the next decade, extremely powerful information technologies will become as ubiquitous in educational settings as they are in other aspects of people's daily lives. They are almost certain to provoke fundamental changes in learning environments at all levels of the education system. Many of the implications of technology are beyond people's speculative capacity. At the time of issuing the Commission's first report, for example, few could have predicted the sweeping effects of the Internet on education and other segments of society. The range of computational devices and their applications is expanding exponentially, fundamentally changing how people think about communication, connectivity, information systems, educational practices and the role of technology in society.

While it is always risky to predict the future, it appears clear that advances in technology will continue to impact the world of education in powerful and provocative ways. Many technology-driven advances in the design of learning environments, which include the integration of assessment with instruction, will continue to emerge, and will reshape the terrain of what is both possible and desirable in education. Advances in curriculum, instruction, assessment and technology are likely to continue to move educational practice toward a more individualized and mastery-oriented approach to learning. This evolution will occur across the K-16+ spectrum. To manage learning and instruction effectively, people will want and need to know considerably more about what has been mastered, at what level, and by whom.

Consider the possibilities that might arise if assessment is integrated into instruction in multiple curricular areas and the resultant information about student accomplishment and understanding is collected with the aid of technology. In such a world, programs of on-demand external assessment such as state achievement tests might not be necessary. Instead, it might be possible to extract the information needed for summative and program evaluation purposes from data about student performance continuously available both in and out of the school context.

Technology could offer ways of creating, over time, a complex stream of data about how students think and reason while engaged in important learning activities. Information for assessment purposes could be extracted from this stream and used to serve both classroom and external assessment needs, including providing individual feedback to students for reflection about their learning strategies and habits. To realize this vision, additional research on the data representations and analysis methods best suited for different audiences and different assessment objectives would clearly be needed – and is certainly doable.

We can therefore imagine a future in which the audit function of assessments external to the classroom would be significantly reduced or even unnecessary because the information needed to assess students, at the levels of description appropriate for various monitoring purposes, could be derived from the data streams generated by students in and out of their classrooms.

A metaphor for such a radical shift in how one “does the business of educational assessment” exists in the world of retail outlets, ranging from small businesses to supermarkets to department stores. No longer do these businesses have to close down once or twice a year to take inventory of their stock. Rather, with the advent of automated checkouts and barcodes for all items, these enterprises have access to a continuous stream of information that can be used to monitor inventory and the flow of items. Not only can business continue without interruption, but the information obtained is far richer, enabling stores to monitor trends and aggregate the data into various kinds of summaries. Similarly, with new assessment technologies, schools would no longer have to interrupt the normal instructional process at various times during the year to administer external tests to students. Nor would they have to spend significant amounts of time preparing for specific external tests peripheral to the ongoing activities of teaching and learning.

Extensive technology-based systems that link curriculum, instruction and assessment at the classroom level might enable a shift from today’s assessment systems, which use different kinds of assessments for different purposes, to a balanced design in which the three critical features of *comprehensiveness*, *coherence*, and *continuity* would be ensured. In such a design, assessments would provide a variety of evidence to support educational decisionmaking (*comprehensiveness*). The information provided at differing levels of responsibility and action would be linked back to the same underlying conceptual model of student learning (*coherence*) and would provide indications of student growth over time (*continuity*).

Clearly, technological advances will allow for the attainment of many of the goals that educators, researchers, policymakers, teachers and parents have envisioned for assessment as a viable source of information for educational improvement. When powerful technology-based systems are implemented in classrooms, rich sources of information about student learning will be continuously available across wide segments of the curriculum and for individual learners over extended periods of time. This is exactly the kind of information we now lack, making it difficult to use assessment to truly support learning. The major issue is not whether this type of data collection and information analysis is feasible in the future. Rather, the issue is how the world of education anticipates and embraces this possibility, and how it will explore the

resulting options for effectively using assessment information to meet the multiple purposes served by current assessments and, most important, to enhance student learning.

A Concluding Comment

It has been noted that the best way to predict the future is to invent it. Without doubt, multiple futures for curriculum, instruction and assessment could be invented on the basis of synergies that we know exist among information technologies and contemporary knowledge of cognition and measurement. While we are a considerable distance away from implementing the types of fully integrated instructional and assessment systems envisioned above, there are steps that can be taken now that would put us on the path to such a future. That future is certainly a critical component of realizing the sweeping transformation of the American educational landscape advocated by the New Commission Report.

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