

STUDENTS AT THE CENTER

TEACHING AND LEARNING
IN THE ERA OF THE COMMON CORE

A JOBS FOR THE FUTURE PROJECT

CURRICULAR OPPORTUNITIES IN THE DIGITAL AGE

MARCH 2012

THE STUDENTS AT THE CENTER SERIES

By David H. Rose and Jenna W. Gravel

EDITORS' INTRODUCTION TO THE STUDENTS AT THE CENTER SERIES

Students at the Center explores the role that student-centered approaches can play to deepen learning and prepare young people to meet the demands and engage the opportunities of the 21st century. *Students at the Center* synthesizes existing research on key components of student-centered approaches to learning. The papers that launch this project renew attention to the importance of engaging each student in acquiring the skills, knowledge, and expertise needed for success in college and a career. Student-centered approaches to learning, while recognizing that learning is a social activity, pay particular attention to the importance of customizing education to respond to each student's needs and interests, making use of new tools for doing so.

The broad application of student-centered approaches to learning has much in common with other education reform movements including closing the achievement gaps and providing equitable access to a high-quality education, especially for underserved youth. Student-centered approaches also align with emerging work to attain the promise and meet the demands of the Common Core State Standards.

However, critical and distinct elements of student-centered approaches to learning challenge the current schooling and education paradigm:

- > Embracing the student's experience and learning theory as the starting point of education;
- > Harnessing the full range of learning experiences at all times of the day, week, and year;
- > Expanding and reshaping the role of the educator; and
- > Determining progression based upon mastery.

Despite growing interest in student-centered approaches to learning, educators have few places to which they can turn for a comprehensive accounting of the key components of this emerging field. With funding from the Nellie Mae Education Foundation, Jobs for the Future asked nine noted research teams to synthesize existing research in order to build the knowledge base for student-centered approaches to learning and make the findings more widely available.

The topic of this paper, as with each in the series, was selected to foster a deeper, more cohesive, research-based understanding of one or more core elements of student-centered approaches to learning. The authors in this series: synthesize and analyze existing research in their areas; identify what is known and where gaps remain related to student-centered approaches to learning; and discuss implications, opportunities, and challenges for education stakeholders who put students at the center. The authors were asked to consider the above definition of student-centered approaches, but were also encouraged to add, subtract, or critique it as they wished.

The authors were not asked explicitly to address the Common Core State Standards. Nevertheless, the research proceeded as discussions of the Common Core were unfolding, and several papers draw connections with that work. The thinking, learning, and teaching required for all students to reach the promised outcomes of the Common Core provide a backdrop for this project. The introductory essay looks across this paper and its companion pieces to lift up the key findings and implications for a new phase in the country's quest to raise achievement levels for all young people.

The nine research papers are loosely organized around three major areas of inquiry—learning theory; applying student-centered approaches; and scaling student-centered learning—although many of the papers necessarily cross more than one area:

1. LEARNING THEORY: What does foundational and emerging research, particularly in the cognitive and behavioral sciences, tell us about how students learn and about what motivates them to learn?

Mind, Brain, and Education

Christina Hinton, Kurt W. Fischer, Catherine Glennon

Motivation, Engagement, and Student Voice

Eric Toshalis, Michael J. Nakkula

2. APPLYING STUDENT-CENTERED APPROACHES: How are student-centered approaches to learning implemented? What is the nature of teaching in student-centered learning environments? How can students who are underrepresented in postsecondary education be engaged earlier and perform well in the math and reading activities that scaffold learning? How are advances in technology customizing curriculum and changing modes of learning to meet the needs of each student?

Teachers at Work—Six Exemplars of Everyday Practice

Barbara Cervone, Kathleen Cushman

Literacy Practices for African-American Male Adolescents

Alfred W. Tatum

Latino/a and Black Students and Mathematics

Rochelle Gutierrez, Sonya E. Irving

Curricular Opportunities in the Digital Age

David H. Rose, Jenna W. Gravel

3. SCALING UP STUDENT-CENTERED APPROACHES TO LEARNING: How have schools sought to increase personalization and with what outcomes for learning? What is the relationship between assessment and student-centered approaches? What can districts do to support student-centered approaches to learning?

Personalization in Schools

Susan Yonezawa, Larry McClure, Makeba Jones

Assessing Learning

Heidi Andrade, Kristen Huff, Georgia Brooke

Changing School District Practices

Ben Levin, Amanda Datnow, Nathalie Carrier

A number of distinguished researchers and practitioners serve as advisors to *Students at the Center* including Scott Evenbeck, founding president of the New Community College, City University of New York; Charles Fadel, Visiting Scholar, Harvard Graduate School of Education, MIT ESG/IAP, and Wharton/Penn CLO; Ronald Ferguson, Senior Lecturer in Education and Public Policy, Harvard Graduate School of Education and the Harvard Kennedy School; Louis Gomez, Professor and the John D. and Catherine T. MacArthur Foundation Chair in Digital Media and Learning, Graduate School of Education and Information Studies, UCLA; Susan Moore Johnson, Professor and the Jerome T. Murphy Professor of Education, Harvard Graduate School of Education; Jim Liebman, Simon H. Rifkind Professor of Law, Columbia University School of Law; Miren Uriarte, Professor, College of Public and Community Service, University of Massachusetts, Boston; and Arthur VanderVeen, Vice President, Business Strategy and Development at Compass Learning.

To download the papers, introductory essay, executive summaries, and additional resources, please visit the project website: www.studentsatthecenter.org.

Over the coming months, Jobs for the Future and the Nellie Mae Education Foundation will craft opportunities to engage a broad audience in the conversation sparked by these papers. We look forward to building a shared understanding and language with you for this important undertaking.



Nancy Hoffman, Adria Steinberg, Rebecca Wolfe

Jobs for the Future



JOBS FOR THE FUTURE

Jobs for the Future identifies, develops, and promotes education and workforce strategies that expand opportunity for youth and adults who are struggling to advance in America today. In more than 200 communities across 43 states, JFF improves the pathways leading from high school to college to family-sustaining careers.

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The **Nellie Mae Education Foundation** is the largest charitable organization in New England that focuses exclusively on education. The Foundation supports the promotion and integration of student-centered approaches to learning at the middle and high school levels across New England. To elevate student-centered approaches, the Foundation utilizes a strategy that focuses on: developing and enhancing models of practice; reshaping education policies; increasing the body of evidenced-based knowledge about student-centered approaches and increasing public understanding and demand for high-quality educational experiences. The Foundation's initiative and strategy areas are: District Level Systems Change; State Level Systems Change; Research and Development; and Public Understanding. Since 1998, the Foundation has distributed over \$110 million in grants.

WWW.NMEFOUNDATION.ORG

ABOUT THE AUTHORS

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TABLE OF CONTENTS

INTRODUCTION	1
ADVANCES IN THE NEUROSCIENCE FOUNDATIONS OF HUMAN VARIABILITY	2
CUSTOMIZATION AND INDIVIDUAL DIFFERENCES	5
UNIVERSAL DESIGN FOR LEARNING	7
PRINT AND ITS DISABILITIES	12
THE PROMISE OF NEW TECHNOLOGIES	14
REALIZING THE PROMISE OF NEW TECHNOLOGY FOR STUDENT-CENTERED LEARNING	16
Student-centered Means of Representation	19
Student-centered Means of Action and Expression	17
Student-centered Means of Engagement	20
A FEW CAVEATS ABOUT DIGITAL TECHNOLOGIES	22
STATE OF THE ART: WHAT HAS CHANGED TO MAKE CURRICULA MORE STUDENT CENTERED	24
Public Policy	24
State and District Initiatives	25
Market Models	25
Classroom Practices	26
FUTURE DIRECTIONS	27
ENDNOTES	28
REFERENCES	29

INTRODUCTION

Historically, most classrooms have been “curriculum centered” rather than “student centered.” The core elements of the curriculum in most schools—textbooks and related print materials—are fixed, standardized, uniform, one-size-fits-all, but students, on the other hand, are anything but uniform or standardized. As a consequence, teachers, and the students themselves, must adapt or accommodate the curriculum as best they can in order to meet the challenge of individual differences. Or more commonly, many students must simply endure the extra hurdles and inefficiencies of trying to learn from a curriculum that is neither designed for them nor accessible to them. This is not a promising foundation for student-centered learning.

Recent federal and state policies (e.g., the National Instructional Materials Accessibility Standard; the National Educational Technology Plan) have foreshadowed a very different future, one in which curricula are designed from the outset to be flexible and nimble enough to adapt readily to individual differences. These new policies reflect the conjunction of advances in two very different fields: research in the neuroscience of individual differences and human variability; and advances in the design of multimedia learning technologies. Together, these advances provide a new and promising foundation for the realization of student-centered learning. They point to a general framework for educational practice—universal design for learning—that capitalizes on their intersection to optimize student learning for every student.

ADVANCES IN THE NEUROSCIENCE FOUNDATIONS OF HUMAN VARIABILITY

Digital analytic and imaging tools have produced an explosion of information about the changes in the brain that underlie learning. This has led to the emergence of whole new fields: cognitive science; cognitive neuroscience; affective neuroscience. In another paper in the *Students at the Center* series, Christina Hinton, Kurt W. Fischer, and Catherine Glennon beautifully summarize many of the important implications about teaching and learning that have emerged from that research. Here, we amplify one important aspect of that research: individual differences in learning.

Related Paper in the *Students at the Center* Series¹

Mind, Brain, and Education, by Christina Hinton, Kurt W. Fischer, and Catherine Glennon.

In any field of science, the early focus is typically on discovering what is most general, most universal. In the study of child development, for example, Jean Piaget's pioneering work focused on capturing what was universal about children's maturation—describing the common structures and stages through which every child's thinking and reasoning developed (Piaget 1952; Piaget & Inhelder 1969). Later, as a field matures, the focus typically expands to include the sources and extent of variation and individuation. In child development, hundreds of researchers have articulated and revised Piaget's general stages, demonstrating enormous variability in those "universal" structures as well as the many kinds of individual and environmental differences that profoundly affect the generalities that Piaget described.

Within the various fields of neuroscience, still early in their development, most researchers have focused on understanding the basic properties of the nervous system and the universal principles of its function.

As the field has begun to mature, there has been an increasing attention to the reality of variation—identifying not only what is most general about the nervous system but also the sources and range of variability. Early researchers in neurology focused on global measures of variability (e.g., the variation in size or weight of the brain; the overall amount of its myelination). For behavioral correlates, they similarly focused on global measures (e.g., IQ). Later, psychologists—especially those who worked with neurological patients—developed more differentiated views. Howard Gardner's (1993) multiple intelligences and Robert Sternberg's (1985) triarchic framework are examples of the increasing attention to the patterns of individual differences.

The explosion of neuroscience research made possible by digital imaging devices has led to much richer articulations of variation in the nervous system and to its expression in observable individual differences. What the new images reveal is a brain that is highly differentiated and specialized: There are estimated to be at least 20 different regions of specialization for vision alone. We now know, for example, from many dynamic images of the brain in action that the color of an object is processed in a very different region of the brain than its size, shape, or location. Even more striking, we now know that faces are processed in slightly different regions of the temporal cortex than other objects, like utensils or cars or flowers.

What is most relevant to our discussion here is that each of the brain's specialized functions is a source of variability and individual differences. There are individuals who cannot learn to recognize people by their faces (a condition called prosopagnosia) yet can easily learn to recognize most other objects and even recognize people by their clothes or style of hair (Grill-Spector, Knouf, & Kanwisher 2004; Nestor, Plaut, & Behrmann 2011). For those individuals, the specific region of the brain specialized for recognizing faces



series

is compromised. But face recognition, like most other specializations of the brain, lies along a continuum: There are individuals who are “gifted” and those who are “disabled,” and every kind of variation in between.

To take another example, the brain has many specialized areas for learning about sound. One region is specialized to process the pitch of a sound, and other areas process location (i.e., where sound is coming from), timbre, and duration. Each of those specializations is a source of variation. For example, some individuals have “perfect pitch” (Drayna 2007). We now know that they have a specific variation in their anatomy—a planum temporale that is larger on one side than the other (Keenan et al. 2001). Individuals in any population will vary along a continuum from perfect pitch to perfectly awful pitch. But a person’s perfect pitch does not indicate that they will have “perfect timbre.”

The variation goes far beyond variation in just the way we perceive the world. Consider faces again. As noted, there is typically an area in the temporal lobe that specializes in face recognition—differentiating one person’s face (say, Bill’s) from everyone else’s. But there is a very different area (in the medial cortex) that specializes in learning to recognize the emotion in Bill’s face, differentiating his angry face from his sad face (Lewis et al. 2003; Pessoa et al. 2006). Yet another area (in the frontal cortex) specializes in making and recognizing facial movement and expressions (Leslie, Johnson-Frey, & Grafton 2004). This latter area allows you to generate your own facial expressions, and it underlies your ability to recognize and imitate the facial expression of someone else (as actors do). All of these, and many more, are specialized ways in which our brains learn about faces. And all of them are discrete sources of individual variation.

It is important to pause a moment to consider the sources of individual variation. Confronted with the sharp differentiation of brain images, many educators and researchers assume that the sources of individual

differences are largely genetic. In reality, the human brain at any stage in its development reflects a complex history of the interplay between genetics and environment. What we see in the brain’s individual patterns of specialization is as much a result of culture as of genetics. As one example, consider again perfect pitch. We know that genetics plays a role: Individuals with Williams’s syndrome or autism have a much higher incidence of perfect pitch. But it is also true that culture plays a role—the incidence of perfect pitch is much higher in some culture than others—specifically in cultures where pitch is an especially important factor in communication and social development. Nowhere are the effects of cultural differences more sharply drawn than in the *Students at the Center* series paper by Rochelle Gutiérrez and Sonya E. Irving. They make a strong case for the role of culture and society in differentiating not only how mathematics is realized but also how it is learned.

Related Paper in the *Students at the Center* Series²

Latino/a and Black Students and Mathematics, by Rochelle Gutiérrez and Sonya E. Irving.



In this new landscape of richly differentiated functionality in the brain, general global measures like IQ seem anachronistic and inarticulate. Individuals are complex composites of variation in a great many different capabilities—not only within a single modality like vision or hearing but also at higher levels of integration, such as cognition, language, and memory. *Variation is not only universal, it is ubiquitous.*

Given the reality of human variation, what are the implications for a student-centered curriculum? On the face of it, it seems clear that a curriculum that is “student centered” for one individual might not be so for another. For students in the margins, the point is clear. A poster or map in a social studies lesson that highlights Republican states in red and Democratic states in blue would represent political information well for most students. For those who are blind, or



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even just color blind, such a representation would hardly be considered student centered. Nor would a math lesson that requires excellent reading seem student centered for a student who is dyslexic. At the other end of the spectrum, a ninth-grade history text that is written with a sixth-grade vocabulary and syntax (as many are) is hardly student centered for the student who needs to be challenged with the vocabulary and syntax of a twelfth grader. A truly student-centered lesson would take into account the considerable differences between students.

How many sources of variation must a lesson designer consider in order to meet the criteria of student centered? Students with sensory and physical disabilities—even students with dyslexia—are striking cases, but perhaps these are special cases, not entirely representative. In what ways must it be possible to “customize” a curriculum so that it is student centered enough to be effective?

CUSTOMIZATION AND INDIVIDUAL DIFFERENCES

For the full population of students, does the availability of options—customization—actually improve performance? A considerable body of research shows it does with various types of customization (Lopez & Sullivan 1992; Miller & Kulhavy 1991; Renninger, Ewen, & Lassher 2002). However, plenty of studies show no effects (Bates & Wiest 2004; Wright & Wright 1986).

Not surprisingly, customization itself is not the answer. In fact, customization in general is unlikely to be effective. For it to do so in any educational setting requires consideration of two things: the individual pattern of abilities of the student; and the specific goals and demands of the learning task. Most efforts to customize consider only one of these.

Consider an analogy. Customization in medicine is critical: The medicine that is life saving for one individual may cause life-threatening side effects for another. The explosive growth of bioinformatics, with medications increasingly selected on the basis of their match to individual genotypes, is one sign of the increasing role of customization in medicine. Penicillin does not work in general; it works only for specific individuals, and for some, it is poisonous. And that is only half of the picture. The choice of medications must reflect not only differences among individuals but also differences in the goal or purpose of treatment. Penicillin works for bacterial infections but not for viruses or strokes. Some medicines are essential in a crisis, but others are more valuable for

prevention. Successful customization depends on knowing the individual (which antibiotic is likely to produce fewer side effects?) and also on knowing the demand or purpose (is an antibiotic or a blood thinner needed?).

Designing a lesson that can be student centered first depends upon recognizing the important variations among students that might make a lesson less accessible or less informative for some students. Second, it depends upon recognizing the important variations in the design and implementation of tasks or lessons. Of particular concern are aspects of the task that are not “construct relevant”—that is, where aspects of the lesson design interfere with what is being taught. In the civics example above, color is actually construct irrelevant because the lesson is about politics, not color discrimination. The use of a color in the map requires each student to have the same abilities in color discrimination—that is, the color is helpful (i.e., student centered) for most but poses an unacceptable barrier for a few.

Yet effective customization also requires paying particular attention to aspects of the tasks that are in fact construct relevant. For example, a civics teacher who wants to develop students’ persuasive *writing* skills might assign an essay that asks them to describe their perspectives on the benefits of living in either a “Red” or “Blue” state. In this case, developing persuasive *writing* skills is considered construct relevant, and customizing the assignment



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by allowing students to make a poster, create a skit, etc. on this same topic would interfere with a student's opportunity to learn. Instead, it would be optimal to offer other kinds of customizable supports but only for those aspects of the task that are not essential to the goals of learning. For example, the teacher might offer students the option of utilizing a graphic organizer, speech-to-text technology, or word prediction. With these scaffolds in place, the teacher could customize the assignment for different students, providing options that would allow both student and teacher to focus better on the construct relevant goal: developing the higher-level strategies of persuasive writing.

In summary, the result of these advances in the neurosciences is a radical alteration of what it means to be student centered. Any classroom or any process of curriculum design that focuses on addressing the "average" learner cannot reasonably be thought of as learner centered—there are simply no average learners to center on. Instead, any learner-centered classroom must focus on meeting the challenge of diversity, providing a curriculum that is as articulated and differentiated as the learners themselves.

Given the hundreds of ways students differ from one another, what guidance is there for teachers and curriculum designers on what is essential to include and what can be ignored? What is the least amount of options that must be provided so that a curriculum can support student-centered learning—for all students, not just a few?

UNIVERSAL DESIGN FOR LEARNING

The new field of universal design for learning (UDL) provides a framework and guidelines for making decisions about instructional designs that meet the challenge of diversity. To be effective, those decisions cannot be made on the basis of perceived preferences or intuitions but rather on research in the learning sciences (particularly about individual differences) and proper educational design.³

In architecture, universal design focuses on the design of products, buildings, or environments so they can be used readily by the widest possible range of users (Mace, Hardie, & Place 1991). Virtually all U.S. architects now create buildings that are designed from the outset to reduce or eliminate architectural barriers through designs that consider the needs of diverse people. This practice is recognized as more cost effective and more equitable than retrofitting buildings or providing customized accommodations to individuals who are unable to navigate poorly designed structures. Universally designed environments are engineered for flexibility and designed to anticipate alternatives, options, and adaptations that meet the challenge of diversity. While originally conceived to meet the needs of individuals with disabilities, universal designs make buildings that are more accessible and functional for everyone.

A good example of universal design in action comes from the history of television captioning. When captioning first became available, it was an expensive

add-on, intended for people with hearing impairments. Designing captioning into every television has turned out to be a better and more universal design: it now benefits not only those with hearing impairments but also exercisers in health clubs, travelers in airports, individuals working on their language skills, and couples who go to sleep at different times. The key to universal design is building options into initial designs, making better choices available for everyone.

Universal design for learning is one part of the overall movement toward universal design. The term UDL emphasizes the special purpose of learning environments. They are not created to provide access to information (that is the role for libraries and the Internet). Rather, they foster the changes in knowledge and skills that we call learning. While providing access to information is often essential to learning, it is not sufficient. Success also requires that the means for learning—the pedagogical goals, methods, materials, and assessments of instruction—are also accessible. UDL is a process to ensure that the means for learning, and their results, are equally accessible to all students.

The framework and guidelines for UDL are based on research and practice from multiple domains within the “learning sciences”: education; developmental psychology; cognitive science; and cognitive neuroscience. Research in those fields guides both the scope of the pedagogy that UDL addresses (i.e., the critical elements of teaching and learning) and



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the range of individuals it addresses (i.e., the critical elements of individual differences).

At its simplest, the scope of UDL is based on three principles:

- > Provide multiple means of representation.
- > Provide multiple means of action and expression.
- > Provide multiple means of engagement.

These principles address three critical features of any teaching and learning environment: the means by which information is presented to the learner; the means by which the learner is required to express what he or she knows; and the means by which students are engaged in learning (Rose & Meyer 2002; Rose, Meyer, & Hitchcock 2005).

While there are many ways to articulate the fundamentals of teaching and learning, the choice of these three foundational principles stems from their commonality across many aspects of theory and research in the learning sciences. Consider the field of cognitive neuroscience where it is common to think of three broad divisions of the “learning brain”: the pattern recognition capabilities in the posterior regions of the cortex; the motor and executive capabilities in the frontal regions of the cortex; and the affective or emotional capabilities in the medial regions of the nervous system. While this division is an oversimplification, it is a common articulation that draws on Alexander Luria’s (1973) classic work and has been elaborated and modified by many others (Cytowic 1996; Goldberg 2001; Barsalou, Breazeal, & Smith 2007; Rosenzweig, Breedlove, & Watson 2005; Sanguinetti 2007). It is by design that the three principles of UDL match up well with this neuroscientific framework. To be systematic in considering learning differences, they address in turn the perceptual learning of the posterior cortex, the strategic and motor learning of the anterior cortex, and the affective or emotional learning of both the medial and orbital frontal cortex.

Beyond cognitive neuroscience, researchers and theorists in other learning sciences have adopted very similar frameworks to consider the scope of teaching and learning. Among the most prominent, Lev Vygotsky (1978), the preeminent Russian psychologist, and Benjamin Bloom (1984), the American educational

theorist, adopted similar three-part frameworks for their foundations.

From the three principles, nine guidelines form the foundation of UDL (see *Figure 1 on page 9*). These guidelines articulate the principles, and their main purpose is to guide educators and curriculum developers in using research-based means of addressing the wide range of individual differences that any classroom typically experiences.

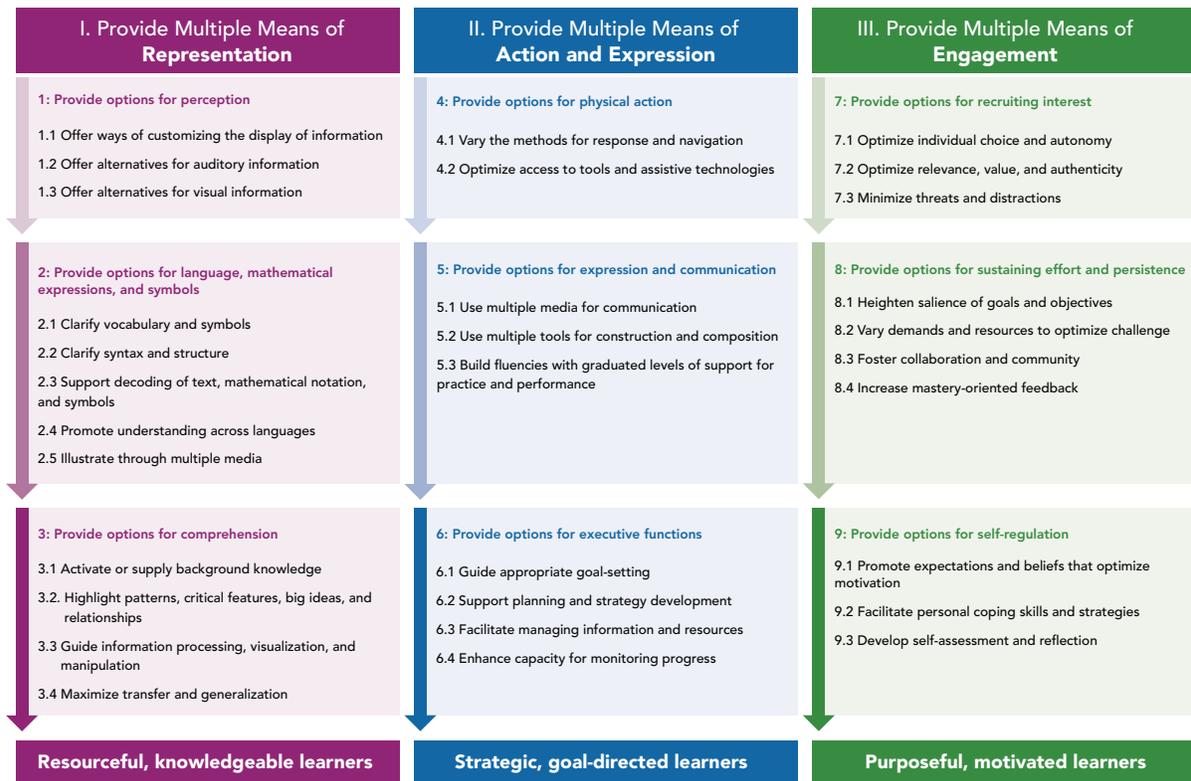
The top of the columns in *Figure 1* emphasize the three basic principles. At the bottom of each column are the goals: students who are, each in their own way, resourceful and knowledgeable, strategic and goal-directed, purposeful, and motivated. Each column, in turn, articulates guidelines and checkpoints for achieving those goals in ways that can be customized enough to succeed among students who are, like all students, quite differentiated.

These guidelines and checkpoints derive from research in the cognitive and affective neurosciences, research that helps to articulate the landscape of learning and its sources of variability. Let us explore just one of the columns—multiple means of expression—to illustrate the origin of the guidelines.

Figure 2 (on page 9) illustrates the lateral surface of the human cerebral cortex.

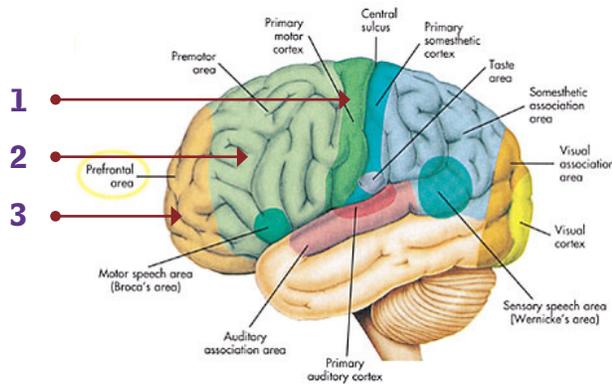
To the left (in green and yellow) are the frontal lobes. Decades of neuroscience research have demonstrated that this is the locus of our abilities to act skillfully and strategically. Moreover, we know that the frontal lobes can be articulated into different regions, each of which contributes to the overall ability to act strategically and successfully. In fact, there is a regular progression of functions in the frontal lobes from back to front. At the rear of the frontal lobes—in what is called the primary motor cortex (**1** in the diagram)—lie the neural networks that are most directly involved in producing simple voluntary motor movement. Just forward of that—in what is sometimes called the secondary motor cortex (**2**)—are networks that coordinate simple movements into the elaborate and fluent skills that are the hallmarks of human ability. Just forward of that—in what is called the tertiary motor cortex or the executive or prefrontal cortex (**3**)—are the networks that provide “executive functions,” underlying the especially human ability not only to be skillful but to be strategic and planful

FIGURE 1
UNIVERSAL DESIGN FOR LEARNING GUIDELINES



Source: CAST (2011)

FIGURE 2
THE LATERAL SURFACE OF THE HUMAN CEREBRAL CORTEX



Source: CAST (2011)

in our actions. The prefrontal cortex allows us to set goals for ourselves, choose effective strategies rather than respond impulsively or reflexively, and monitor our progress and change courses of action as needed—the executive functions.

Each of these specialized areas within the frontal lobes are important sources of individual differences

that are reflected in the guidelines. Students differ in their primary motor capabilities (their ability to move and perform basic motor acts). They also differ in their abilities to learn to develop simple movements into fluent skills and abilities (e.g., writing, speaking, dancing, drawing, playing basketball). And they differ in their abilities to develop competent functions for executing those skills and movements (e.g., setting appropriate goals for themselves, choosing effective strategies and skills, monitoring their own progress).

These areas of specialization are largely independent as sources of variability: The same student who is very awkward and clumsy may be highly strategic and planful. An extreme example, of course, is Stephen Hawking, the physicist who has very little capacity for simple voluntary movement but enormous capacity for strategic thinking and executive functions.

Although creating a framework for articulating the sources of individual variability is important, the next and most valuable step is to identify how to cope with that variability in creating student-centered curricula. The UDL guidelines recommend research-based

options—customizable resources and strategies—that can be used to meet the challenge of variability.

Figure 3 (on page 11) shows the guidelines and their checkpoints for the second principle—providing multiple means of action and expression—in relation to the brain image shown earlier.

Each of the guidelines recommends options. No single tool, method, or path to success will be optimal for every student. Only by providing well-chosen options can we create learning environments that are effectively student centered for all students. The guidelines, and the checkpoints that elaborate them, provide research-based recommendations for the kinds of options that are important to consider in designing any learning environment. In Figure 4, one of the checkpoints—providing options that guide appropriate goal-setting—is highlighted as an example of how the guidelines are supported.

In the Web-based version of the guidelines, clicking on any checkpoint brings up a box like that illustrated in Figure 4 (on page 11).⁴ In that box are three things critical for educators: an elaboration of the meaning and importance of the checkpoint; links to practical examples of the options that are recommended; and links to research evidence for the efficacy of such options.

Clicking on the “view examples and resources” link brings you to a webpage of relevant examples and resources for goal-setting (see *Figure 5 for a partial sample page on page 11*).

Clicking on the “view latest evidence and scholarly research” link brings up a bibliography of relevant research findings and scholarly opinions or summaries (see *Figure 6 for a partial sample page on page 11*).

All of this is a little hard to demonstrate in print. In a Web-based, digital version, a click on a checkpoint or guideline brings you to the information that you need. And not only is it difficult to navigate this print version, but many examples and resources cannot even be demonstrated in this format because they are natively interactive, multimedia, and “digital.”

Interactive, Multimedia, and “Digital” UDL Guidelines

For a much more interactive version of the guidelines, the research behind each guideline, and multimedia examples of its practice, see: www.udlcenter.org/aboutudl/udlguidelines

For an even more interactive and imaginative version of the guidelines created by teacher/educators in Howard County, Maryland, see <http://www.udlwheel.mdonlinegrants.org/> or check out UDL Links, their new app for the iPad.

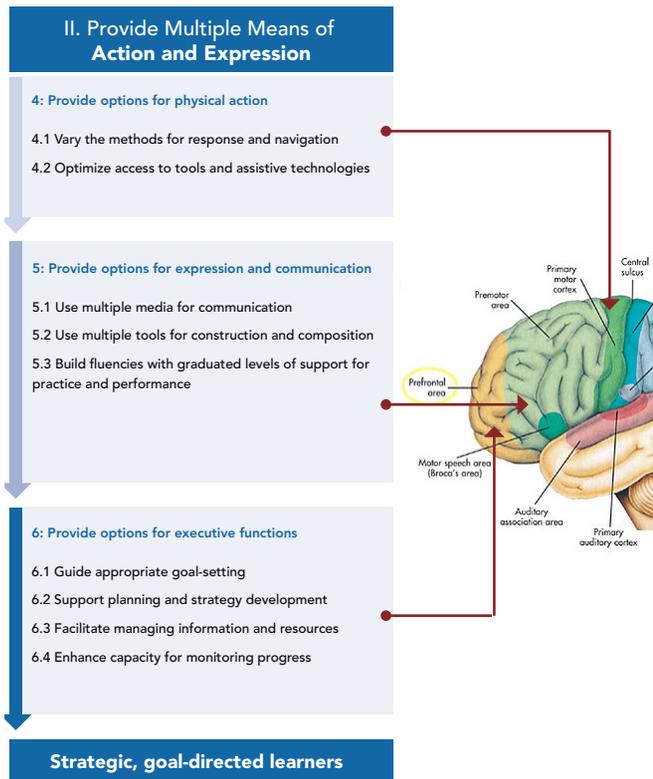


In light of these illustrations of the power of the guidelines, it is a good time to think about the difference between new and old media. Just as it is difficult to present the UDL guidelines in print, constructing or implementing a curriculum that is student centered is too hard a task to undertake with tools from the sixteenth through nineteenth centuries.



No single tool, method, or path to success will be optimal for every student. Only by providing well-chosen options can we create learning environments that are effectively student centered for all students.

**FIGURE 3
GUIDELINES AND THEIR CHECKPOINTS
FOR THE SECOND PRINCIPLE**



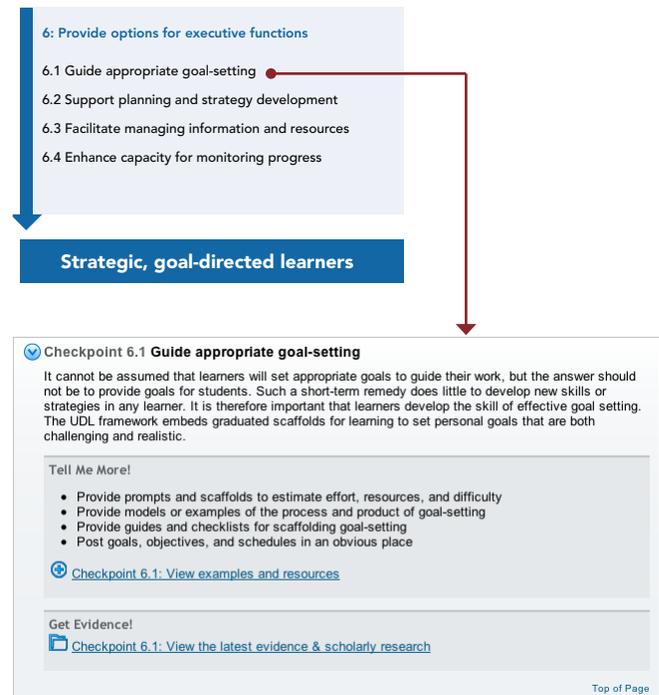
Source: CAST (2011)

**FIGURE 5
PARTIAL SAMPLE PAGE OF RELEVANT
EXAMPLES AND RESOURCES**

Example/Resource	Why UDL?
<p>Goal Setting Worksheets</p> <p>Find templates for goal-setting worksheets to use with your students to support their organizational skills.</p> <p>Age Group: Elementary, Middle Content Area: All Areas Cost: Free Technology Involved: Internet connection to access; can also choose to download and print out</p>	<p>Why UDL? These organizational worksheets are great examples of strategies that guide students' goal-setting.</p> <p>See also: 9.1: Promote expectations and beliefs that optimize motivation</p>
<p>Exploring Language</p> <p>Exploring Language provides leveled support for learning about language and setting goals. See how students and artists explore and express their thoughts through poetry and song.</p> <p>Age Group: K-12 Content Area: English, poetry, songwriting Cost: Free Technology Involved: Internet connection</p>	<p>Why UDL? Exploring Language offers students models and tips as to how to set goals that make the writing process more effective.</p> <p>See also: 8.2: Vary demands and resources to optimize challenge</p>
<p>Helping My Students Set Goals the Smart Way</p> <p>Elona Hartjes shares the insights, resources, and practical classroom strategies that have earned her A Teacher of Distinction Award.</p> <p>Age Group: K-12 Content Area: All areas Cost: Free Technology Involved: Internet connection</p>	<p>Why UDL? Elona's post "Helping my students set goals the smart way" offers ideas on effective goal-setting.</p> <p>See also: 9.1: Promote expectations and beliefs that optimize motivation</p>

Source: CAST (2011)

**FIGURE 4
CHECKPOINTS PROVIDING OPTIONS**



Source: CAST (2011)

**FIGURE 6
PARTIAL SAMPLE PAGE OF RELEVANT
RESEARCH FINDINGS AND SCHOLARLY
OPINIONS OR SUMMARIES**

Checkpoint 6.1: Guide appropriate goal-setting

II. Provide Multiple Means of Action and Expression	Summary
<p>Executive Function</p> <ul style="list-style-type: none"> • Checkpoint 6.1 • Checkpoint 6.2 • Checkpoint 6.3 • Checkpoint 6.4 	<p>Learning can be inaccessible when it requires effective and realistic goal-setting and where there are no options for individuals who differ in such <i>executive functions</i>. Long term and even short terms tasks can raise barriers to learning without the proper embedded support for such goal-setting. The experimental and quantitative evidence listed here indicates the advantages of supports - such as highly explicit goal-setting instruction, varied models, and embedded prompts and scaffolds to estimate effort and task difficulty - for this facet of executive functions. The scholarly reviews and opinion pieces provide additional arguments for why it is important to supports students' in setting their goals. Although some of these articles are dated, they nonetheless continue to provide guidance on supporting effective goal-setting.</p>

[Do you have additional evidence to support this Checkpoint? Tell us!](#)

Experimental and Quantitative Evidence:

Butler, D. L. (1997). The roles of goal setting and self-monitoring in students' self-regulated engagement in tasks. Paper Presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, March 24-28, 1997).

Earley, P. C. (1985). Influence of information choice and task complexity upon goal acceptance, performance and personal goals. *Journal of Applied Psychology*, 70(3), 481-491.

Fleming, V. M. (2002). Improving students' exam performance by introducing study strategies and goal setting. *Teaching of Psychology*, 29(2), 115-119.

Fuchs, L., Bultenworth, J., & Fuchs, D. (1989). Effects of ongoing curriculum-based measurement on student awareness of goals and progress. *Education and Treatment of Children*, 12(1), 63-72.

Fuchs, L. S., Fuchs, D., Karns, K., Hamlett, C. L., Katzaroff, M., & Dutka, S. (1997). Effects of task-focused goals on low-achieving students with and without learning disabilities. *American Educational Research Journal*, 34(3), 513-543.

Source: CAST (2011)

PRINT AND ITS DISABILITIES

In most contemporary classrooms, print remains the primary technology for communication and instruction. Print assumed this position because of its obvious advantages: It is an ideal storage and display medium for information that can be encoded in text or in static images. Thanks to Johannes Gutenberg, print is an inexpensive and portable way to convey the narratives and knowledge of our culture.

As a platform for student-centered learning, however, print is far from ideal. It is a fixed, inert, standardized, “one size fits all” medium—perfect for any classroom in which students are essentially alike. Unfortunately, no classroom is like that. Moreover, the challenge (and opportunity!) of diversity is increasing in the modern era because our culture has demanded education that is more equitable and inclusive—reformed to include not only wealthy white males but women, minorities, people who do not own land, individuals with disabilities, and English language learners.

Print is a poor fit for such diversity, but with no obvious alternatives, students and teachers have adapted to its limits. Classrooms are textbook centered rather than student centered because students, rather than their textbooks, have seemed more adaptable, flexible, and malleable.

But not all students are malleable enough. For some, the strictures of print not only fail to provide a useful platform for student-centered learning but instead impose rigid barriers. For students who are blind,

for example, rendering verbal information into print makes it entirely inaccessible.

For blind students, the limits of print are so onerous that the need for alternatives became obvious as soon as alternative technologies were available. By 1931, when audio recordings and Braille editions were possible, Congress mandated that alternatives to print must be provided to individuals who are blind, have poor vision, are physically disabled, or have organically based reading disabilities. In recent legislation, Congress has used the new term of “print disabilities” to convey the challenges these individuals face. This term is now prominent in federal and state legislation and will soon affect every school and classroom in America. It represents a watershed in education, a harbinger of the future that will have profound effects on the ways we understand what it means to have student-centered learning.

The revolutionary aspect of the term print disabilities is a subtle but remarkable shift in focus. While most labels solely reflect the role of the individual—identifying disability in their personal handicaps or weaknesses—this new term emphasizes the role of the learning environment, specifically the environment of print. The handicap is recognized as not residing wholly “in the child” but rather in the interaction between the child and the medium of print. Print plays some role in who is, or is not, called disabled.

For most of the 500 years since Gutenberg invented the printing press, this focus would have seemed



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very strange. During that time, the dominance of print for literacy and learning was so complete that its strengths completely overshadowed its weaknesses. Unlike any previously available form of communication, print was durable, able to be shared in exact form, and made widely available information that was previously available to a select few.

For some individuals, however, print's weaknesses have always been much more obvious. As alternatives began to emerge (e.g., voice recordings; refreshable Braille devices; digital talking books), print's weaknesses became apparent. As these alternatives became more common, the inaccessibility of print was eventually recognized as an injustice. Laws were enacted to ensure that every student with print disabilities could have an accessible alternative.

These requirements, which apply to every public school in America, represent an important shift in responsibility for providing materials that are, indeed, student centered. However, the laws apply only to students with print disabilities. Advances in educational technologies far beyond Braille and audio books foreshadow a much broader shift in what it means to be student centered.

THE PROMISE OF NEW TECHNOLOGIES

The very “soul” of new media differs radically from that of print; the difference exposes print’s limitations and threatens its central role in our culture. In this regard, print is not alone. All of the media available several decades ago, including audio recordings, Braille, films, and so forth, share a common DNA with print. Each physically embeds (prints) information (in text, sound, or images) in a medium (paper, vinyl, film) to make that information “permanent” so it can be reviewed, replayed, or projected. New media—digital computers, televisions, cell phones, video, iPods—differ fundamentally: They store information as numbers (“digitized”) rather than physically print or embed them in any particular medium. From numbers, those representations can be recreated as needed. The old media printed or embedded information physically in the display medium (a piece of paper or page in a book); the new media store information in a medium that is completely separate from its display. As a result, information is always transformed from one format to another—from an image to digits to store it or from digits to a printed image to view it.

In these transformations, new media take on a very different character, with much greater flexibility as well as other significant advantages over analog or print media. Recognizing these abilities of new media

is critical to understanding their potential for student-centered learning.

Typically, four advantages of digital media are emphasized, all of them linked to increased flexibility or malleability:

Digital media are versatile. Digital media can store and present information in many modalities and formats—text, still image, sound, video, animation, simulations, combinations of text on video, sound in text, video in text, and more (Heimann et al. 1995; Mayer & Massa 2003). Compared with print, and indeed any traditional fixed medium, this versatility is remarkable.

Digital media are transformable. Because the means for display are separable from the content, digital media allow the same content to be displayed in multiple ways. Within a medium, the presentation of content can be altered in a variety of ways to suit the individual or the subject. For example, changes can be made to typeface, font size, font color, sound volume, presentation rate, writing style, and difficulty of information; images can be turned on or off; main ideas can be highlighted (Elkind, Cohen, & Murray 1993; Mayer & Massa 2003; Mayer & Moreno 2003). Transformations from one medium to another are also possible—text-to-speech; speech-to-text; text-to-American Sign Language; text-to-Braille (Elbro,



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Rasmussen, & Spelling 1996; Hasselbring & Williams-Glaser 2000). Speech recognition and text-to-speech tools can be embedded into Web browsers and other software programs via translation algorithms, so that the transformation from one medium to another can take place automatically and when users want to access the material.

Digital media are dynamic by nature (Lanham 1995; Messaris & Humphreys 2006). At the center of a computer is a clock and a processor that sequences operations in time. As a result, digital media are changeable over time. Digital technologies can respond to changing information, the passage of time, and manipulation by events.

Digital media can be manipulated. Because digital media can exist within programmable environments, the medium itself is manipulable (Manovich 2002; Messaris & Humphreys 2006). New media can be manipulated or even programmed by the user. This read/write flexibility allows media to be not only a means of representing information but also a means of constructing or gathering information. In particular, the flexibility of digital media allows the user to act on information—transforming it to make something new, recombining it to solve a problem, linking it to show relationships, or modifying it for personal preferences.

REALIZING THE PROMISE OF NEW TECHNOLOGY FOR STUDENT-CENTERED LEARNING

Whereas the soul of old media is its permanence, the soul of new digital media is its flexibility—the flexibility with which it can be modified, customized, diversely represented, and manipulated. Moreover, that flexibility can be gained without sacrificing the core functionality of print: its permanence. And the flexibility gained in new media leads to entirely different capacities. Capturing those gains for student-centered learning returns us to an educational framework, which we explore based on the three principles of universal design for learning.

STUDENT-CENTERED MEANS OF REPRESENTATION

A curriculum is not student centered when information is presented in the same way to everyone because students differ widely in how they best perceive information, comprehend it, and turn it into usable knowledge. Any one medium of representation—a text, a video, an image, an audio recording, a simulation—and any particular representation within a medium (e.g., a text in English but not Spanish) will ultimately privilege some students over others.

One key step in creating a curriculum that can support student-centered learning is to provide options in the ways information is presented, options that make it more equitably accessible. Within the framework of UDL, this principle is articulated as “provide multiple means of representation.”

That means that information in a visual diagram is presented in an alternative way—like a verbal description or a tactile graphic—so that there is an alternative for students with poor vision. For the persuasive essay, it means providing the essay in both print and digital formats so the words can be automatically read aloud for the dyslexic reader or translated into Spanish for the student who is not a fluent English reader.

Providing these alternatives is where the flexibility of new media is most powerful. New media have a wide range of capabilities for presentation, from natural spoken language (including a wide range of intonation and prosody), to full-motion video and audio, to 3-D graphics, to virtual reality, and to many combinations of those kinds of representations (e.g., both written and spoken language together). Moreover, within a single format like text, new media can quickly, automatically, and easily transform text into many different fonts, sizes, colors, forms of emphasis, and so forth. More significantly, the text can be transformed into entirely different modalities—into voice, ASL, refreshable Braille, even from one language to another. Lastly, new media can easily convey motion, interaction, and sequence—through video, sound, or simulations—and provide options that demonstrate relationships in time and space, dynamic cause and effect, processes and procedures in real or slow motion, etc.

Not only do digital technologies provide better options for customizing presentations to meet the challenge of individual differences, those same



Not only do digital technologies provide better options for customizing presentations to meet the challenge of individual differences, those same technologies also vastly increase the range of concepts that can be conveyed for any student.

technologies also vastly increase the range of concepts that can be conveyed for any student. Digital technologies open up a world of representing content to students in multiple ways. For example, instead of explaining the concept of fractions orally or modeling problems on the board, teachers can turn to online tools that allow students to interact with the content.⁵

As another example, digital technologies enable teachers to share content with students using an array of representations. The teacher could present information on the French Revolution through a slideshow of images that capture the social upheaval that took place, show a closed-captioned video that depicts the steps leading up to the Revolution, or ask students to read a primary source document online (with the option of using text-to-speech, increasing the font size, or enhancing color contrast). Digital technologies provide endless opportunities to represent content in multiple ways, providing a foundation for representations that are student centered because there are options.

STUDENT-CENTERED MEANS OF ACTION AND EXPRESSION

A curriculum is not student centered when all students must express or demonstrate what they have learned in exactly the same way. Students are as varied in their abilities for expression and action as they are in their abilities for accessing information.

Briefly, student variation can be seen at three levels: at the level of physical or motor action (e.g., students with cerebral palsy differ significantly in the ways they can express themselves from many other students); at the level of specific skills or fluency in a particular medium (e.g., students with dyslexia

differ significantly in the ease with which they can express themselves in written text); and at the level of executive function (e.g., students with ADHD syndrome differ significantly in the ways in which they can plan, organize, sustain effort, and complete any significant composition or expression).

As a result of these individual differences, some students may be able to express themselves well in writing but not oral speech, or in a diagram but not in an essay, for example. In reality, no one means of expression will be optimal for all students; providing options for expression is essential.

One set of options, the most general, is to allow or encourage students to express themselves in a variety of different media. A digital environment opens up many new options. For example, in addition to encouraging students to write an essay or create a poster describing the process of mitosis, teachers can suggest that groups of students work together to create an animation of the process using SAM Animation, a free online software that allows users to create stop-action.⁶ Or teachers could ask teams of students to start with a drawing of the process and then upload that drawing into VoiceThread, a free tool for sharing and commenting on images or video files, and narrate the different stages depicted in the image.⁷ Finally, the class could work together to create an online book about mitosis using UDL BookBuilder, a free tool for creating and sharing digital books with embedded learning supports.⁸ An astounding array of new digital technologies can be used to provide options for student expression, and we must find ways to effectively weave these new tools into the classroom.

Nevertheless, providing options in media is not the most important or pedagogical way to make expression more student centered. What is really



Nevertheless, providing options in media is not the most important or pedagogical way to make expression more student centered. What is really important is to provide—within any medium—the graduated supports and scaffolds of a “cognitive apprenticeship.” That is, do not just provide the scaffolds and supports an early learner needs, but calibrate and adjust them to the changes in skill and development that come with practice—a gradual release toward independence. New technologies can provide vastly more differentiated support and scaffolding than was available in the classrooms of print.

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Modeling. One of the most effective techniques for teaching a new skill or strategy is to model it. While human teachers are the best source of modeling (as long as they are themselves skillful in the domain), new media make it possible to embed virtual modeling and mentoring in almost any learning environment. And while print can provide models of *outcomes*—a model of an essay, for example—new technologies can provide virtual or simulated models of the *process* for reaching those outcomes. The explosion of “how-to” videos on YouTube is one indication of the power of new media to mentor through modeling. Thousands of human mentors have made videos in which they demonstrate how to do everything from sharpening knives to juggling them.

The advantages of this kind of modeling are immediately obvious when compared with the tortured and difficult explanations that come in the printed directions for assembling a new bike. In schools, almost any digital medium can embed mentoring videos or animations, providing careful modeling for skills that once seemed almost impossible to model in print: public speaking; scientific inquiry; painting; composition; social skills.

Furthermore, digital media offer new opportunities for modeling complex concepts through simulations and animations that visually display abstract ideas, highlight critical features, and connect to students’ everyday lives. For example, *SimCalc Mathworlds™*, an interactive computer software program, develops students’ understanding of the mathematical concepts of proportions, rates, and linear functions by embedding a range of models, simulations, and animations to promote student learning. The software aims to support students in “linking visual forms (graphs and simulated motions) to linguistic forms (algebraic symbols and narrative stories of motion)”

(Roschelle et al. 2007). *SimCalc Mathworlds™* has a statistically significant effect on students’ ability to understand the concepts of rate and proportionality (Roschelle et al. 2007). One student’s comment on the benefit of *SimCalc Mathworlds™* illustrates the power of modeling through new digital technologies: “The simulation thing and the stepper really helps [me learn] a lot on that thing because you can really see what you’re doing instead of just like on a sheet of paper. . . . And then on that you can actually see it moving and it’s like you can experience it so it’s easier to understand” (Roschelle et al. 2007).

Graduated Scaffolding. Providing opportunities for practice is a critical aspect of growth and development in the nervous system.⁹ A key aspect of teaching any form of skillful expression is guided practice with scaffolding that can be gradually released, and today’s new technologies have the flexibility to incorporate these important instructional supports. Well-designed digital media offer a broad palate of learning supports and challenges to find what Vygotsky (1978) calls the “zone of proximal development”—that place where optimal learning occurs for individual students. With carefully designed digital technologies, students can practice a new skill or new knowledge with just the right amount of challenge and support, supports that can be adjusted to the student—a key aspect of student-centered learning.

There is a growing body of research and development in using technology to provide the supports and scaffolds that promote effective practice. As just one example from our own work, C. Patrick Proctor and his colleagues (2009) conducted a study of a UDL online vocabulary and reading comprehension intervention designed for both English- and Spanish-speaking students. The tool included a range of embedded supports: Spanish translation; a multimedia glossary; Spanish and Spanish-English bilingual “coaches” to prompt for understanding; illustrations depicting the content of the text; and an “electronic work log” that gathered students’ responses to comprehension prompts. The embedded supports significantly improved vocabulary knowledge.

Other research reveals the positive effects of graduated scaffolding across a wide spectrum of individual learners. Consider, for example, research

on Literacy by Design, a technology-based approach to literacy instruction that combines UDL principles and research-based reading instruction for young students with significant cognitive disabilities (Coyne et al. 2010). LBD embeds a range of scaffolds into the design of the online environment such as: text-to-speech; a multimedia glossary; videos and photo essays to supply background knowledge; prompts to apply reading comprehension strategies (e.g., predict, question, retell, connect); prompts to echo read, partner read, and read independently; and pedagogical agents who offer prompts, think alouds, and models. Results indicate significant gains on the Woodcock Johnson Test of Achievement III Passage Comprehension subtest and that the digital scaffolding has a strong effect on students' word attack skills, listening comprehension, and understanding of alphabet and book knowledge.

Progress Monitoring. Very few skills can be developed without timely and relevant feedback. New media learning environments are increasingly able to provide ongoing assessment data by carefully monitoring student progress and providing increasingly relevant and challenging feedback to both students and teachers. New digital learning environments can support teachers in collecting valuable data for measuring student growth as well as making necessary adjustments to instruction. These technologies do not replace teachers in monitoring the progress of students; rather, they provide valuable, timely, and student-centered sources of information. With that information available, teachers can teach more effectively, making strategic, knowledgeable, and motivating decisions for all of their students.



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Related Paper in the *Students at the Center Series*¹⁰

For more information on assessments in the context of student-centered learning, see *Assessing Learning*, by Heidi Andrade, Kristen Huff, and Georgia Brooke.



Moreover, these digital technologies can be updated and improved based upon learner feedback. One thing that is so powerful and motivating about video games is their ability to monitor progress and adjust the level of challenge and support accordingly (Gee 2005). This kind of responsiveness makes them enormously more learner centered than traditional games, even though they often set much higher demands for performance and competence. Historically, few educational technologies have been as responsive to the learner as the most rudimentary video games.

Technologies are now available to remedy that situation. For example, in 2002, Carnegie Mellon University launched the Open Learning Initiative to develop online postsecondary courses that “enact the kind of dynamic, flexible, and responsive instruction that fosters learning” (Open Learning Initiative 2011). These courses were developed to both compliment face-to-face instruction and to serve as stand-alone courses that do not require official instructors (Lovett, Meyer, & Thille 2008). To support student learning, the courses embed a range of features: simulations; options in navigation through content; and frequent opportunities to practice new knowledge. Furthermore, the OLI courses focus on supporting students to monitor their own progress and providing them with immediate, targeted feedback. “Mini-tutors” offer students hints and advice as they practice new skills and are especially

designed to focus on common mistakes and common misconceptions (Lovett, Meyer, & Thille 2008).

A study evaluating the effectiveness of an OLI statistics course highlights the powerful learning that can take place when the types of progress monitoring that are common in today's video game technology are transferred to an instructional environment. When the course was used by itself, student learning gains "were at least as good as in a traditional, instructor-led course" (Lovett, Meyer, & Thille 2008). Furthermore, when the course was used in conjunction with face-to-face instruction, students in the treatment group "learned a full semester's worth of material in half as much time and performed as well or better than students learning from traditional instruction over a full semester" (Lovett, Meyer, & Thille 2008).

All of the above are merely examples of scaffolding. It is not that print technologies cannot provide scaffolding; it is that the lack of versatility and inertness of print limit the most critical aspect of scaffolding: the ability to adjust to the changing relationship between the learner and the goal of instruction. In contrast, well-designed (especially universally designed) learning environments, like well-designed video games and simulations, often provide many types of scaffolds, many levels of scaffolding, and many levels of difficulty so that apprentices are always in their "zone of proximal development."

STUDENT-CENTERED MEANS OF ENGAGEMENT

A curriculum is not student centered when it only uses one means to engage and motivate all students. At the core of teaching is the motivational foundation for learning and for preparing students for a lifetime of further, intrinsically motivated learning. One of print's biggest limitations in helping teachers achieve that goal is its weakness for adjusting to the level of frustration, boredom, challenge, or threat that its tasks present to each individual learner. The same chapter may be boring to one student, terrifying or threatening to another, and bewildering to a third. None of these are constructively engaging.

The UDL guidelines call for multiple means of engagement because students differ markedly in the ways in which they can be engaged or motivated to learn. Some students are highly engaged by spontaneity and novelty; other are disengaged, even frightened, by those same things. Authentic tasks are one source of engagement, but clearly what is "authentic" is highly culturally and developmentally sensitive—what is authentic to one student seems foreign and off-putting to others. In reality, no one means of engagement will be optimal for all students; providing multiple options for engagement is essential (Rose & Meyer 2002; CAST 2011).

New digital technologies widen the range of options for student-centered engagement. Within the UDL framework are three aspects of engagement: recruiting interest; sustaining effort and persistence; and building self-regulation (CAST 2011).

For **recruiting interest**, especially among digital natives (Prensky 2001), new media can provide a rich, interactive panoply of resources. For example, students seeking to learn about orangutans can take a "virtual field trip" and see these animals via live webcams at the San Diego Zoo.¹¹ They also can communicate with bloggers and videographers in China or Africa. These resources are not engaging because they are novel; they are engaging because they are authentic and normative. Marc Prensky (2001) emphasizes that today's students are "digital natives": they "have spent their entire lives surrounded by and using computers, video games, digital music players, video cams, cell phones, and all the other toys and tools of the digital age." Given their facility and comfort with technology, it is no wonder that digital natives find print to be anachronistic—it is certainly not a part of the culture that they have grown up in and certainly not a part of the culture into which they will matriculate.

For **sustaining effort and persistence**, new media provide extended and authentic opportunities to build apprentice communities of practice. Digital tools expand the lines of communication and collaboration for students across districts, states, and counties: ePals is a free online community that enables students from all over the world to connect and share experiences. Glogster is a free tool that allows students to create "interactive posters" to

communicate ideas. And Blogger is a free resource that allows students to create their own blogs.¹²

Hoot.me exemplifies the idea of using digital technologies to foster collaboration and communication.¹³ This new company seeks to provide students with a way to turn their Facebook pages into “study mode” (Hoot.me 2011). Hoot.me transforms a Facebook page by connecting peers and their teachers through features such as chat options, video/voice conferencing, and screen sharing. Such tools make it easier for students to collaborate and learn from one another.

The third UDL guideline within engagement recommends options for building *self-regulation*. The ultimate goal of education is to build the student’s own capacity for self-regulation. One of the self-regulation skills that students need to develop is the ability to recognize and react to appropriate feedback. Students are quite diverse in their initial reactions to feedback—some of it biologically based, as Christina Hinton, Kurt W. Fischer, and Catherine Glennon show in their *Students at the Center* paper:

When students with this anxiety-linked gene engage in a computer literacy instruction program without feedback, they perform lower than students without this gene. However, when the program is adjusted to include positive feedback that motivates and informs students as they work, those with the anxiety-linked gene have higher outcomes than those without it. Adjusting instruction to meet each student’s particular needs can often move students from failure to proficiency.

The capacity of digital technologies to adjust the level and kind of feedback is just one of the ways in which they can help in providing multiple means of engagement. Most important, the guidelines recommend options that develop students’ self-assessment and reflection skills as a way to promote self-regulation. When offered an array of options and flexibility in the student-centered classroom, it is essential for students to build an awareness of their individual strengths and weaknesses so that they can select the tools and strategies that provide the right amount of challenge and support. With young children, it may be necessary for teachers to scaffold students in selecting the options that work best for them. As students grow older, it is important that they develop skills that enable them to independently seek out the customizable features that optimize their learning.

In sum, the student-centered classroom harnesses the flexibility of new media to provide a diverse range of students with multiple means of representation, expression, and engagement. The student-centered classroom harnesses the flexibility of new media for the teacher, providing a rich set of tools and resources to elevate and differentiate teaching. In that rich environment, the teacher can be both a content provider and the classroom’s most experienced and savvy teacher/learner, a model of the kind of expert learner students can emulate.

Related Paper in the *Students at the Center* Series¹⁴

Mind, Brain, and Education, by Christina Hinton, Kurt W. Fischer, and Catherine Glennon.



series



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A FEW CAVEATS ABOUT DIGITAL TECHNOLOGIES

Although there are numerous advantages of digital technologies, an awareness of their limits is essential as well. First, poorly designed digital learning tools give the illusion of progress when in fact they simply replicate print tools. For example, scanning a printed document into a digital version does not ensure that students with a range of strengths and weaknesses can access and comprehend the content. As with print, digital tools must be thoughtfully designed with careful consideration in terms of both access and learning supports. As new digital learning tools flourish and our understanding of learner variability advances, curricula that cannot meet that challenge will be increasingly recognized as “print disabled.”

Further, it is important to take into account the impact of the digital divide when considering the classroom potential of digital technologies. Although computers are becoming more ubiquitous in classrooms and students’ homes, some families still lack access to technology. A recent Pew Research Center report found an association between technology use and household income: 87 percent of U.S. households making more than \$75,000 a year have Internet access at home, compared with only 40 percent of households making less than \$30,000 a year (Jansen 2010).

This disparity holds important implications for the use of digital technologies in school settings. A survey of a diverse group of economically disadvantaged youth in California found that 91 percent of the students believe that the Internet is either “highly important”

or “important” to their school work (Robinson 2009). Yet only 31 percent of students have high-quality Internet access at home, 35 percent have low-quality access, and 34 percent have no access. Respondents with limited access at home or without any at all report struggling to complete homework and other school-related tasks due to difficulty making arrangements to use a friend’s or family member’s computer or to finding an open computer in the school’s computer lab or in a public library. This limited access causes a significant amount of stress among students. According to the author, “Feeling pressed for time, they experience emotional angst because they are routinely unable to get adequate time online necessary for their schoolwork.”

Third, it would be impractical to discuss the power of new media without acknowledging the significant costs at the school and district levels. To leverage the potential of technology to meet the needs of diverse learners, the technological infrastructure of many schools would need to be modernized or redesigned. Many schools—and taxpayers—are understandably daunted by the upfront costs of doing so. But in any sector of our society—business, government, entertainment, defense—it is important to consider both the costs of implementing new technologies and the benefits. Moreover, especially in education, it is important to consider the costs of *not* implementing them. Now that many textbooks cost over \$100 each, a tablet computer that can hold many books (including many produced as open education resources or new accessible versions like Pearson’s HTML books) looks like a good investment.



Many schools—and taxpayers—are understandably daunted by the upfront costs of doing so. But in any other sector of our society—business, government, entertainment, defense—it is important to consider both the costs of implementing new technologies and the costs of *not* implementing them.

Moreover, the full costs of not investing in technology must be calculated on a longer timeframe. Many costs come later—when high school and college graduates are unprepared for the modern workplace, unprepared to meet the challenge of global competition. But the most frightening costs come from the failures of our present practices: students who do not graduate at all but join a depressingly predictable—and extraordinarily expensive—pipeline to prisons, unemployment, and dependency.

Fourth, simply acquiring new media does not make for a student-centered approach to learning. Technology must be effectively woven into instruction to support student learning. Districts are often lured into purchasing technology with little thought as to how it can be used to enhance instruction (CITEd 2011). And, even when professional development on the new technology is provided, it often lacks the context teachers need to integrate it with their curricula (Glazer, Hannafin, & Song 2005). Digital technologies are changing rapidly, and it is difficult for schools and districts to keep their teachers up to date on how to use technology to support student learning.

Further, even the best new technologies are not good for some elements of instruction. For example, although digital technologies are effective in supporting students in *reaching* standards through features such as modeling and progress monitoring, they are certainly not effective in *setting* these standards. Distilling critical aspects of content domains and crafting thoughtful curricula that challenge all learners must be left up to experts in content and pedagogy, not to technology.

Finally, technologies are not good at the “emotional work” of the classroom. Classrooms are ultimately about building and enhancing relationships; computers and other online tools and programs are not equipped to do this profoundly human work. Instead, this responsibility lies in the hands, heart, and mind of the classroom teacher, a role that we believe can never be replaced by even the best technology.

The teacher is the emotional center of the classroom, and this role must be recognized and honored. What universally designed materials can do is provide the supportive tools that enhance a teacher’s ability to excel.



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STATE OF THE ART: WHAT HAS CHANGED TO MAKE CURRICULA MORE STUDENT CENTERED

The education landscape is shifting dramatically toward embracing the framework of a universal design for learning as a basis for student-centered learning. With the advent of flexible technologies for teaching and learning, the policy barriers that have kept printed text as the dominant medium have begun to fall. Like many cultural advances, these policy changes began by addressing the needs of those who are most obviously marginalized and disadvantaged by the dominance of print—especially individuals with disabilities—but now promise to benefit everyone. Building on federal and state policies that have guaranteed timely and accessible alternatives to printed instructional materials, the movement to establish UDL as the guiding set of principles for curricular design (K-12 and postsecondary, general, special education) will help shape teaching and learning that are learner centered for all.

PUBLIC POLICY

With the 2004 reauthorization of the Individuals with Disabilities Education Act, Congress established the National Instructional Materials Accessibility Standard. The act stipulated that students with “print disabilities” (those who cannot access print due to blindness, a visual impairment, a physical disability, or an organically based reading disability) had a right, a civil right, to an alternative version of textbooks and related instructional materials. NIMAS represents a marked change in how the field of education thinks

about disability and remediation. The conversation has shifted from exclusively addressing weaknesses inherent in individual students—for example, dyslexia—to also focusing on weaknesses in the primary medium of instruction: print. In more dramatic terms, NIMAS pushes the education community toward placing the blame on the inflexibility of print rather than on students (Rose & Vue 2010).

Since the adoption of NIMAS, the establishment of the National UDL Task Force in 2008 has continued to make UDL a powerful player in the education policy landscape. The task force, comprised of more than 40 general education, special education, and civil rights organizations, advocates for UDL in federal, state, and local policy. Thanks to its efforts, UDL is now defined in federal statute. The Higher Education Opportunity Act of 2008, enacted with strong bipartisan support, established a statutory definition for universal design for learning and signifies a federal recognition of the power of UDL to enhance instruction and to increase learning opportunities for all students. The definition includes the three principles of UDL (representation, action and expression, and engagement) and highlights the need to incorporate appropriate supports and challenges into instruction in order to reduce barriers for all learners. The act also emphasizes the need for teacher education programs on integrating strategies consistent with UDL into instruction. Providing teachers with a solid understanding of UDL will equip them with strategies to address the diverse range of students’ strengths and weaknesses.



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The task force has also played an important role in advocating for the inclusion of UDL in the upcoming reauthorization of No Child Left Behind (which has reverted to its former name, the Elementary and Secondary Education Act). In late 2011, members of the task force held a congressional briefing to share their recommendations for the reauthorization and to increase awareness and understanding of UDL among key congressional staff.

Strong references to UDL can also be found in the U.S. Department of Education's National Educational Technology Plan, released in 2010 (U.S. Department of Education 2010). This plan guides the use of information and communication technologies in transforming American education and provides concrete goals that can inform state and local educational technology plans, as well as inspire research, development, and innovation. UDL is cited throughout this plan to promote the use of technology to expand learning opportunities for all students. As a way to model UDL, an excerpt from the National Educational Technology Plan has been transformed into a UDL learning environment with an array of embedded options and supports.¹⁵

Finally, trends in federal funding show promise for the implementation of a more student-centered, digital curriculum. For example, the National Science Foundation has adopted a UDL-based initiative to develop science curricula that are designed from the start with UDL principles and options to ensure that science education will be more student centered.

STATE AND DISTRICT INITIATIVES

Attention to developing and implementing UDL and other student-centered approaches is increasing in many states and districts. Maryland's Universal Design for Learning Act (HB 59/SB 467), enacted in 2010, is the nation's first state-level UDL legislation.

The act established a state-level task force to explore the incorporation of UDL principles into Maryland's education systems, and in 2011 the State Board of Education voted unanimously to adopt its recommendations. In its final report, *A Route for Every Learner*, the task force supported using UDL principles during the development of curricula and assessments, in the selection process for textbooks, instructional materials, and technology, and in all appropriate state plans (UDL Task Force 2011). Maryland is the first state to adopt UDL to guide curriculum design for all students.

Strides in implementing UDL can also be seen in state universities. Ensuring Access through Collaboration and Technology (EnACT) is a U.S. Department of Education-funded demonstration project designed to ensure that students with disabilities can attain their postsecondary educational goals in the California State University. EnACT focuses on providing faculty with comprehensive training on UDL, with "Faculty Learning Communities" designed to promote reflection and feedback on the incorporation of UDL into instruction, as well as an online library of accessible materials and resources.¹⁶

Other states are making gains on a district level. In 2003, Bartholomew Consolidated School Corporation, an Indiana district serving 11,000 students, began implementing UDL in a pilot school. Today, UDL principles are applied to one degree or another in all of the district's 19 schools.¹⁷

MARKET MODELS

Groundwork for implementing UDL more broadly has also been demonstrated through corporate initiatives to develop customized learning approaches. These initiatives give a glimpse of what may lie ahead: educational materials that are responsive to the array of strengths and weaknesses of today's learners.



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NIMAS has affected the publishing industry profoundly: it has shown publishers the popularity of offering multiple versions of textbooks. Presently, only those students with print disabilities are entitled to digital versions, yet publishers are beginning to realize that accessible versions will benefit all students.

NIMAS has sparked some publishers to get ahead of the curve, creating digital versions and making them available to students without print disabilities. For example, in 2009 Pearson introduced fully accessible e-versions of its traditional printed textbooks.¹⁸

“Pearson HTML books” incorporate a variety of UDL features, such as: customization of text size and layout; text-to-speech; definitions of key vocabulary; non-linguistic illustrations of important concepts; highlighting of main ideas; options in physical navigation; compatibility with assistive technology devices; and more.

Platform makers are also beginning to explore more customized supported learning environments. For example, Inkling is developing interactive, multimedia versions of textbooks for the iPad. This new company transforms traditional textbooks into versions that offer such features as links to primary sources and videos, note-taking space, virtual tours, assessment questions with instant feedback, and the ability to share notes and questions with peers and with the teacher (7X7SF 2011).

CLASSROOM PRACTICES

Thomas Hehir of the Harvard Graduate School of Education consistently makes an important point about the locus of educational change. As he has told us, “If it doesn’t happen in the classroom, it doesn’t happen!” In most classrooms in America, the kinds of practices we have described do not happen, but the number of classrooms where these practices do happen is growing rapidly. And there are many signs of relevant advances in the kinds of tools and methods that teachers use every day. For examples with rich video and descriptive models and resources, take a look at the websites of Edutopia, the National Center on Universal Design for Learning, and the International Association for K-12 Online Learning.¹⁹ The explosion of alternative learning environments enabled by new technologies is another indication

of the rapidly changing ecology (see Florida Virtual Schools, iZone, Nimble Tools, WEB 2.0, ISTE). And when you enter modern public schools like High Tech High in San Diego or Boston Tech Academy, the advantages—for almost every student—of better tools and more flexible methods are immediately evident.

It is important to emphasize, because it is often a concern for traditional educators, that these new environments for learning are not dominated by their computers or technologies, nor are students isolated by their computer screens. Rather, the classrooms are active, vibrant, inquisitive, and social. Students have more ways to communicate and build knowledge together. And with more ways to communicate, more students succeed.

FUTURE DIRECTIONS

We believe, and recent policy directives suggest, that the way education is practiced can change dramatically in coming years.

One of the key changes could be a shift away from rigid curricula—where learners have to adapt to various barriers and inefficiencies—toward flexible and customizable curricula that are well designed for diversity. Digital technologies, and principles like those in the UDL framework, can play an essential role in these changes. Like many cultural advances, these changes would begin by addressing the needs of those who are most obviously marginalized and disadvantaged by existing practices, but they would ultimately benefit everyone. The aspirations of school reformers going back to *Brown v. Board of Education* to make a high-quality education available to all are, perhaps for the first time, actually possible (Minow 2009).

The shift to new, universally designed curricula foreshadows a future where change is continuous rather than intermittent. Traditional curricula have been limited (some would say disabled) because they cannot adapt to the differences between students; they are also limited in their ability to adapt to changes over time. The problem is not just that textbooks are outdated quickly because they cannot learn about changes in the environment. The real problem is that textbooks are outdated quickly when they do not learn about changes in the student. Video games can be powerful and motivating in part because they can monitor individual progress carefully and adjust the level of challenge and support

accordingly. This kind of responsiveness makes them feel enormously more learner centered than traditional games or activities, even though they often set much higher demands for performance and competence. Few educational technologies are as responsive to the learner as rudimentary video games.

There is another important way in which the future seems promising. It is possible to design media, especially social media, that get smarter with use. They can be designed to be continually enhanced and developed by users who add content, evaluations, pedagogy, models, and data. What will make a modern learning environment student centered is not just that it will be responsive to learners but that it will be co-constructed by them.

Ultimately, what will separate new curricula from old is that they will reflect a new ecology for learning. That new ecology will put students at the center of the learning environment. And all students will not only learn, each in their own way; they also will teach. Every curriculum will not only teach, it will learn. In so doing, we will create an optimal ecology for learning, one in which the paths to learning are rich and diverse enough for *all* our students.



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ENDNOTES

¹ See series paper: <http://www.studentsatthecenter.org/papers/mind-brain-and-education>

² See series paper: <http://www.studentsatthecenter.org/papers/latino-black-students-mathematics>

³ The literature on “learning styles” overlaps with UDL in many of its goals but has been troubled in its methods precisely because it lacks grounding in the empirical sciences of both individual differences and instructional design (Clarke 2001).

⁴ See: <http://www.udlcenter.org/aboutudl/udlguidelines>

⁵ The National Council of Teachers of Mathematics’ *Illuminations* (<http://illuminations.nctm.org/ActivitySearch.aspx>) is a free online tool that offers a range of virtual manipulatives that facilitate students’ understanding of a variety of math concepts. These virtual manipulatives offer novel ways to present students with new information.

⁶ See movies: <http://www.sanimation.com/>

⁷ See: <http://voicethread.com/>

⁸ See: <http://bookbuilder.cast.org/>

⁹ See *Mind, Brain, and Education*, by Christina Hinton, Kurt W. Fischer, and Catherine Glennon. <http://www.studentsatthecenter.org/papers/mind-brain-and-education>

¹⁰ See series paper: <http://www.studentsatthecenter.org/papers/assessing-learning>

¹¹ See: <http://kids.sandiegozoo.org/animal-cams-videos>

¹² See: <http://www.epals.com/groups/about/pages/epals-overview.aspx>; <http://edu.glogster.com/>; and <http://www.blogger.com>

¹³ See: <http://www.crunchbase.com/company/hoot>

¹⁴ See series paper: <http://www.studentsatthecenter.org/papers/mind-brain-and-education>

¹⁵ See: <http://cast.org/netp/page/NETP/128/>

¹⁶ See: U.S. Department of Education Funded Centers that Support UDL. Retrieved on December 5, 2011, from <http://www.osepideasthatwork.org/udl/support.asp>

¹⁷ See: <http://www.bcsc.k12.in.us/site/default.aspx?PageID=1>

¹⁸ See: <http://www.pearsonschool.com/>

¹⁹ See: <http://www.udlcenter.org/>; <http://www.edutopia.org/>; and <http://www.inacol.org/>

REFERENCES

- 7x7SF. 2011. "Inkling Reinvents Textbooks as Interactive, Multimedia Learning Tools on the Tablet." Accessed on December 5, 2011. <http://www.7x7.com/tech-gadgets/inkling-reinvents-textbooks-interactive-multimedia-learning-tools-tablet>
- Barsalou, L.W., Breazeal, C., & Smith, L.B. 2007. "Cognition as Coordinated Non-cognition." *Cognitive Processing*. Vol. 8, No. 2.
- Bates, E.T. & Wiest, L.R. 2004. "Impact of Personalisation of Mathematical Word Problems on Student Performance." *The Mathematics Educator*. Vol. 14, No. 2.
- Bloom, B.S. 1984. *Taxonomy of Educational Objectives*. Boston, MA: Allyn and Bacon.
- CAST. 2011. *Universal Design for Learning Guidelines*, Version 2.0. Wakefield, MA: Author.
- CITEd. 2011. "Lessons Learned for Effective Technology Implementation." Accessed on November 5, 2011. http://www.cited.org/index.aspx?page_id=206
- Clarke, R.E. 2001. *Learning From Media: Arguments, Analysis and Evidence*. Greenwich, CT: Information Age Publishing.
- Coyne, P., Pisha, B., Dalton, B., Zeph, L.A., & Smith, N.C. 2010. "Literacy by Design: A Universal Design for Learning Approach for Students With Significant Intellectual Disabilities." *Remedial and Special Education*. Available at <http://rse.sagepub.com/cgi/doi/10.1177/0741932510381651>
- Cytowic, R.E. 1996. *The Neurological Side of Neuropsychology*. Cambridge, MA: MIT Press.
- Drayna, D.T. 2007. "Absolute Pitch: A Special Group of Ears." *Proceedings of the National Academy of Sciences*. Vol. 104, No. 37.
- Elbro, C., Rasmussen, I., & Spelling, B. 1996. "Teaching Reading to Disabled Readers with Language Disorders: A Controlled Evaluation of Synthetic Speech Feedback." *Scandinavian Journal of Psychology*. Vol. 37, No. 2.
- Elkind, J., Cohen, K., & Murray, C. 1993. "Using Computer Based Readers to Improve Reading Comprehension of Students with Dyslexia." *Annals of Dyslexia*. Vol. 43.
- Gardner, H. 1993. *Multiple Intelligences: The Theory In Practice*. New York, NY: Basic Books.
- Gee, J.P. 2005. "Learning by Design: Good Video Games as Learning Machines." *E-Learning and Digital Media*. Vol. 2, No. 1.
- Glazer, E., Hannafin, M.J., & Song, L. 2005. "Promoting Technology Integration through Collaborative Apprenticeship." *Educational Technology Research and Development*. Vol. 53, No. 4.
- Goldberg, E. 2001. *The Executive Brain: Frontal Lobes and the Civilized Mind*. New York, NY: Oxford.
- Grill-Spector, K., Knouf, N., & Kanwisher, N. 2004. "The Fusiform Face Area Subserves Face Perception, Not Generic Within-category Identification." *Nature Neuroscience*. Vol. 7.
- Hasselbring, T.S. & Williams Glaser, C. 2000. "Use of Computer Technology to Help Students with Special Needs." *The Future of Children*. Vol. 10, No. 2.
- Heimann, M., Nelson, K., Tjus, T. & Gillberg, C. 1995. "Increasing Reading and Communication Skills in Children with Autism through an Interactive Multimedia Computer Program." *Journal of Autism and Developmental Disorders*. Vol. 25, No. 5.
- Hoot.me. 2011. Accessed on December 5, 2011. <http://hoot.me>
- Hoot.me Crunchbase profile. 2011. Accessed on December 5, 2011. <http://www.crunchbase.com/company/hoot>
- Jansen, J. 2010. "Use of the Internet in Higher-income Households." Pew Research Center. Accessed on December 5, 2011. <http://pewinternet.org/Reports/2010/Better-off-households.aspx>
- Keenan, J.P., Thangaraj, V., Halpern, A.R., & Schlaug, G. 2001. "Absolute Pitch and Planum Temporale." *NeuroImage*. Vol. 14.
- Lanham, R.A. 1995. *The Electronic Word: Democracy, Technology, and the Arts*. Chicago, IL: The University of Chicago Press.

- Leslie, K.R., Johnson-Frey, S.H., & Grafton, S.T. 2004. "Functional Imaging of Face and Hand Imitation: Towards a Motor Theory of Empathy." *NeuroImage*. Vol. 21.
- Lewis, S., Thoma, R.J., Lanoue, M.D., Miller, G.A., Heller, W., Edgar, C., et al. 2003. "Visual Processing of Facial Affect." *Neuroreport*. Vol. 14.
- Lopez, C.L. & Sullivan, H.J. 1992. "Effect of Personalization of Instruction Context on the Achievement and Attitudes of Hispanic Students." *Education Technology Research and Development*. Vol. 40, No. 4.
- Lovett, M., Meyer, O., & Thille, C. 2008. "The Open Learning Initiative: Measuring the Effectiveness of the OLI Statistics Course in Accelerating Student Learning." *Journal of Interactive Media in Education*. Accessed on December 5, 2011. <http://jime.open.ac.uk/2008/14>
- Luria, A.R. 1973. *The Working Brain*. New York, NY: Basic Books.
- Mace, R., Hardie, G., & Place, J. 1991. "Accessible Environments: Toward Universal Design." In W.E. Preiser, J.C. Vischer, & E.T. White, eds. *Design intervention: Toward a More Humane Architecture*. New York, NY: Van Nostrand Reinhold.
- Manovich, L. 2002. *The Language of New Media*. Cambridge, MA: MIT Press
- Mardis, M., Everhart, N., Smith, D., Newsum, J., & Baker, S. 2010. *From Paper to Pixel: Digital Textbooks and Florida Schools*. Tallahassee, FL: PALM Center, Florida State University.
- Mayer, R.E. & Massa, L.J. 2003. "Three Facets of Visual and Verbal Learners: Cognitive Ability, Cognitive Style, and Learning Preference." *Journal of Educational Psychology*. Vol. 95, No. 4.
- Mayer, R.E. & Moreno, R. 2003. "Nine Ways to Reduce Cognitive Load in Multimedia Learning." In R. Bruning, C.A. Horn, & L.M. PytlikZillig, eds. *Web-based Learning: What Do We Know? Where Do We Go?* Greenwich, CT: Information Age Publishing.
- Messaris, P. & Humphreys, L. 2006. *Digital Media: Transformations in Human Communication*. New York, NY: Peter Lang Publishing, Inc..
- Miller, D.C. & Kulhavy, R.W. 1991. "Personalizing sentences and text." *Contemporary Educational Psychology*. Vol. 16.
- Minow, M. 2009. "Designing Learning for All Learners." In D.T. Gordon, J.W. Gravel, & L.A. Shifter, eds. *A Policy Reader in Universal Design for Learning*. Cambridge, MA: Harvard Education Press.
- Nestor, A., Plaut, D.C., & Behrmann, M. 2011. "Unraveling the Distributed Neural Code of Facial Identity through Spatiotemporal Pattern Analysis." *Proceedings of the National Academy of Sciences*. Vol. 108, No. 24.
- Open Learning Initiative. 2011. Accessed on December 5, 2011. <http://oli.web.cmu.edu/openlearning/initiative>
- Pessoa, L., Japee, S., Sturman, D., & Ungerleider, L.G. 2006. "Target Visibility and Visual Awareness Modulate Amygdala Responses to Fearful Faces." *Cerebral Cortex*. Vol. 16.
- Piaget, J. 1952. *The Origins of Intelligence in Children*. New York, NY: International Universities Press.
- Piaget, J. & Inhelder, B. 1969. *The Psychology of the Child*. New York, NY: Basic Books.
- Prensky, M. 2001. "Digital Natives, Digital Immigrants." *On the Horizon*. Vol. 9, No. 5.
- Proctor, C.P., Dalton, D., Uccelli, P., Mo, E., Snow, C.E., & Neugebauer, S. 2009. "Improving Comprehension Online: Effects of Deep Vocabulary Instruction with Bilingual and Monolingual Fifth Graders." *Reading and Writing: An Interdisciplinary Journal*. Vol. 22, No. 10.
- Renninger, K.A., Ewen, L., & Lassher, A.K. 2002. "Individual Interest as Context in Expository Text and Mathematical Word Problems." *Learning and Instruction*. Vol. 1.
- Robinson, L. 2009. "A Taste for the Necessary. A Bourdieuan Approach to Digital Inequality Information." *Communication & Society*. Vol. 12, No. 4.
- Roschelle, J., Tatar, D., Schectman, N., Hegedus, S., Hopkins, B., Knudsen, J., & Stroter, A. 2007. *Scaling Up SimCalc Project: Can a Technology Enhanced Curriculum Improve Student Learning of Important Mathematics?* (Technical Report 01). Menlo Park, CA: SRI International.
- Rose, D.H., & Meyer, A. 2002. *Teaching Every Student in the Digital Age: Universal Design for Learning*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Rose, D.H., Meyer, A., & Hitchcock, C. 2005. *The Universally Designed Classroom: Accessible Curriculum and Digital Technologies*. Cambridge, MA: Harvard Education Press.
- Rose, D.H. & Vue, G. 2010. "2020's Learning Landscape: A Retrospective on Dyslexia." *International Dyslexia Association, Perspectives on Language and Literacy*. Vol. 36, No. 1.
- Rosenzweig, M.R., Breedlove, S.M., & Watson, N.V. 2005. *Biological Psychology: An Introduction to Behavioral and Cognitive Neuroscience, 4th ed.* Sunderland, MA: Sinauer Associates.

Sanguinetti, V.R. 2007. *The Rosetta Stone of the Human Mind: Three Languages to Integrate Neurobiology and Psychology*. New York, NY: Springer.

Sternberg, R.J. 1985. *Beyond IQ: A Triarchic Theory of Intelligence*. Cambridge, UK: Cambridge University Press.

UDL Task Force. 2011. *A Route for Every Learner*. Baltimore, MD: Maryland State Department of Education.

U.S. Department of Education Funded Centers that Support UDL. 2011. Accessed on December 5, 2011. <http://www.osepideasthatwork.org/udl/support.asp>

U.S. Department of Education, Office of Educational Technology. 2010. *Transforming American education: Learning powered by technology (National Technology Education Plan 2010)*. Retrieved from <http://www.ed.gov/sites/default/files/netp2010.pdf>

Vygotsky, L. 1978. *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University.

Wright, J.P., & Wright, C.D. 1986. "Personalised Verbal Problems: An Application of the Language Experience Approach." *Journal of Educational Research*. Vol. 79, No. 6.



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