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AUTHOR	Rose, David; Meyer, Anne
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ABSTRACT

This paper posits that when new technologies in education move beyond their initial stages of development, innovations in curriculum design, teaching strategies, and policies will be driven by the needs of students "at the margin," those for whom present technologies are least effective, students with disabilities, and that all students will be the beneficiaries of these innovations. After discussing the present assistive technologies and their benefits for students with disabilities, the future of universal design for learning is discussed. New technologies are highlighted that are changing our concept of the nature of learning, of media, of the learner, of teaching and learning, and of assessment. The paper concludes that the particular benefits for students with disabilities are that the new technologies will, by necessity, recognize both the reality and virtue of diversity. The technologies of the future will be more, not less, diverse, and they will engage many kinds of learners. It is predicted that the implicit goals of education will change from homogenization to diversification--identifying and fostering the inherent diversity among all students, identifying new kinds of learning, new kinds of teaching, and new kinds of success. (CR)

The Future is in the Margins: The Role of Technology and Disability in Educational Reform

David Rose, Ed.D. and Anne Meyer, Ed.D.
CAST

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THE FUTURE IS IN THE MARGINS: THE ROLE OF TECHNOLOGY AND DISABILITY IN EDUCATIONAL REFORM

David Rose, Ed.D. and Anne Meyer, Ed.D.
CAST

INTRODUCTION

In a remarkable work of social history called *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*, Ruth Cowan examines the effects of new technologies in the kitchen. Her main conclusion: new technologies like stoves (which were invented in the 18th century and replaced traditional cooking on the open hearth) did not generally make less work for mother. But stoves did transform our culture's concept of what constituted a meal, what was meant by cooking, and even who and what a kitchen was for. Most important, the new technologies of the kitchen democratized cuisine—bringing meals that were more nutritious, more differentiated (multiple dishes, multiple courses), and more attractive to a wide range of households where such meals had been previously unavailable.

In our view, the effects of new technologies in education will be similar. These new technologies will not make less work for teachers. But they will transform the work—making it more nutritious (in Piaget's sense of aliments for learning), more differentiated, more engaging, and more democratized. Perhaps most important, these new tools will change our very concept of learning, and thus of teaching.

When new technologies move beyond their initial stage of development, innovations in curriculum design, teaching strategies, and policies will be driven by the needs of students "at the margin," those for whom present technologies are least effective—most prominently, students with disabilities. The beneficiaries of these innovations will be ALL students.

THE PRESENT: ASSISTIVE TECHNOLOGIES

Most educational technologies in classrooms are at the early stages of adoption. Like most new technologies in the early stages, these educational technologies are presently being used in "traditional' ways, they are new tools being used to do "old" things. Word processors, calculators, and electronic learning games are good examples—these tools provide improvements in efficiency over print-based technologies (e.g. pencils and paper) but they do not fundamentally change the nature of the educational enterprise.

For students with disabilities, technology tools can make a dramatic difference, but they are still being used in traditional, "assistive" ways. These tools primarily provide access to traditional activities that are otherwise inaccessible. New technologies have been remarkably effective in this assistive role; even the most disparaging critic of technology in the classroom usually praises the remarkable benefits of assistive technologies for students with disabilities.

Examples providing evidence of the power of technology for individuals with disabilities are not difficult to find. For individuals with motor disabilities (who may not have the fine motor control required to manipulate a pencil, keyboard. or mouse), the advantages of expanded keyboards, single switch devices, head-mounted infra-red pointers, speech recognition software and word prediction are obvious. Similarly, refreshable Braille devices, talking word processors, screen readers, screen enlargers, and tactile graphic pads offer clear advantages individuals who are blind.

It is not hard to envision the power of new access technologies currently being developed in laboratories all over the world: implanted sensory chips (such as cochlear implants) for both hearing and seeing, neural control devices for robotic arms and legs, convertible wheelchairs that adapt to both sitting and standing positions, and cognitive prostheses for memory deficits.

THE FUTURE: UNIVERSAL DESIGN FOR LEARNING

While assistive technologies are of tremendous value, they will not provoke fundamental changes in education for most students with disabilities. Next-stage educational technologies will go beyond providing better access to existing methods and materials; they will embody fundamentally different concepts of learning (and thus teaching). They will change the learning goals, the teaching methods, and the means of assessment for all students. Several technologies are serving as catalysts for these new ideas and approaches.

NEW TECHNOLOGIES THAT ARE CHANGING OUR CONCEPT OF THE NATURE OF LEARNING

New computer-driven technologies (e.g. PET scans, fMRI, qEEG) are revolutionizing the way in which we are able to study learning as it happens in the brain. These new technologies reveal, in ways that were unimaginable ten years ago, that learning is (1) modular, (2) distributed, (3) parallel, and (4) heterarchical. While a full explication of these observations for understanding the processes of learning is beyond the scope of this paper (see Meyer and Rose, in press) several aspects of the research can be highlighted.

These new tools and methodologies allow us to "see" the brain as it learns—by performing enormously complicated computations on subtle changes in brain activity that are then displayed as a simple "topographical" map of activity on a computer screen. The dominant impression from these computed images is how "modularized" the brain seems to be. It is immediately apparent that the brain learns, for example, about the color of an object in a different region than it learns about the shape of the same object. Moreover, it processes the word "cat" in a different region when it is presented in print than when it is presented in speech, and it uses an entirely different area to compose the word "cat" for speaking. The brain has a large number of such distributed modules that work "in parallel," each highly specialized for learning about specific aspects of the world.

The pattern of activity across different modules clearly depends on the task—different modules are active when one listens to a speech or when one listens to a symphony, for example. In a general sense there is a "signature" of activity in the brain that corresponds to the kind of task being performed. But the distribution of activity for any task also varies across individuals. Each individual reveals a particular "map" of activity—differing both in the proportions of space devoted to each of the modules, and in the composition of different modules used to accomplish the same task. The brain of an individual with perfect pitch, for example, shows a strikingly different distribution of activity from that of an individual with "normal" pitch perception, or one who is "tone deaf."

Significantly, the "map" of activity changes as the brain learns. Recent research has shown that a novice uses very different modules in the brain for the same task than does an expert. New technologies allow us to watch the brain over the course of learning, as it changes from using one set of modules to another. Surprisingly, these new techniques have also shown that the size of an individual processing module can grow (and others can shrink) with experience, even in adults.

New technologies for studying the brain are yielding an increasingly more accurate articulation of the concept of learning—revealing not one generalized learning capacity, but many different "modules" and "distributed processes" for learning within the same brain. Further, it is becoming clear that individual brains differ from each other not in a general ability (like IQ) but in many different kinds of specific abilities.

NEW TECHNOLOGIES THAT ARE CHANGING OUR CONCEPT OF MEDIA

The new media, especially digital media, differ from traditional media in a number of ways. In our view, what is of most significance to the future of education, especially for students with disabilities, is the unequaled flexibility and transformability of digital media.

Print-based media provided some clear advantages over earlier forms of communication such as oratory. Print enabled permanent recording, was portable, and was, at least by the 20th century, relatively inexpensive. In time, and with these advantages, printed text came to dominate learned discourse, and education became dominated by book learning.

The new media (digital text, digital images, digital audio, digital video, digital multimedia, and networked environments) provide many of the advantages of print-based media but they also bring new advantages. Notable is the malleability of the new media. While they, like print, can provide a permanent representation, they do not have the same "fixed" quality as print. Instead, they remain malleable, transformable from one thing to another, more like raw clay than fired pottery.

The consequence is enormous flexibility and the capacity for transformation from one medium to another (e.g. text-to-speech, speech-to-text, text to touch (e.g.Braille), image to touch (haptic images, tactile graphics) and others). In addition, the new media allow multiple representations of meaning that may be used redundantly for clarity, complementarily for enhanced meaning, or even discordantly for multiple meanings (e.g., using text on video (captions), video on text, multiple sound and visual tracks, graphics on video (e.g. signed captioning), sound maps, visual light organs, and others).

The capacity to use multiple media in these and many other ways leads to a more diversified, flexible palette for communication—a palette that takes advantage of the varied strengths and weaknesses of each medium. While the hegemony of printed text has already disappeared in such high-impact fields as advertising, entertainment, and communication in the culture at large, the legacy of print continues in schools. In the years ahead it is clear that text, still dominant in education, will give way to a more intentional use of varied media for instruction.

Instructional designers in the future will tailor their use of media to the task, to different kinds of learning, and different kinds of students. They will use the transformability and flexibility of digital media to reduce the barriers and inefficiencies inherent in fixed, one-size-fits all, printed textbooks. Moreover, they will develop expertise in the representational and expressive qualities of each medium, and the new blends that will develop, so that they can reach a broader set of students, with a broader range of knowledge.

Students with disabilities, for whom the transformations and multiple representations will vastly increase access and learning opportunities, (e.g. talking books, descriptive video, ASL tracks) are the first beneficiaries of the new media. The incidental beneficiaries will include the teachers of subject matters like math, music, geography, physics, and other subjects that have never easily yielded their magic through linear text. But the ultimate beneficiaries will be all learners, each of whom has experienced in one way or another the barriers to motivation and comprehension that an over-reliance on text and other fixed media have wrought.

NEW TECHNOLOGIES THAT ARE CHANGING OUR CONCEPT OF THE LEARNER

The same digital technologies that allow us to examine the biology of learning and to discover and apply the power of new media also allow us to recognize the profound and differentiated (rather than general) ways in which individual learners differ from each other. Continuing the pioneering work of Gardner, Sternberg, and others, this avenue of research continues to show that there is not one "typical" learner with a limited number of variants but instead a great variety of learners—as many as the interactions among modules and architectures in our brains.

In addition, the more differentiated use of media for instruction reveals that individuals who are defined as "learning disabled" within print-based learning environments are not the same individuals who are defined as "learning disabled" within video- or audio-based learning environments. Such revelations splinter the old categorical divisions between "disability" and "ability" and create new descriptors that explicitly recognize the interaction between student and environment in the definition of strengths.

As a result, educators take more notice of the "unusual" strengths of individuals with disabilities – e.g. the prodigious feats of visual memory in the autistic child, or the extraordinary capacity to recognize facial expression in aphasics. In the same context, myriad differences emerge between learners formerly classified in the category of "normal" learners. Against this backdrop, individuals with disabilities fall along a spectrum of difference and the convention of the "regular" student disappears as a normative model.

NEW TECHNOLOGIES THAT ARE CHANGING OUR CONCEPT OF TEACHING AND LEARNING

The flexibility, malleability, and interactivity that characterize new media provide the basis for educational designs that are impossible with traditional fixed methods and materials, designs that emerge as necessary in light of changing concepts of learning and individual differences.

These new designs reflect a more articulated understanding of learning and avoid "presentational" environments (like books and lectures) in favor of truly instructional environments where students are consistently supported in learning how to learn. Individualizable challenge and support are built into every element of the curriculum, every learning experience. Skill-development materials, for example, can be designed to provide built-in models of performance, opportunities for supported practice, immediate feedback, and extended "communities of practice." In that respect, these new environments more closely resemble traditional models of apprentice learning than "book-learning."

Congruent with apprentice models, these new designs exploit the power of new media to individualize and customize, making it possible and imperative to meet the enormous challenge of individual differences (including those who are defined as having disabilities). To do this, they do not provide one-size-fits-all presentations but highly malleable environments that provide the right level of support and challenge for every individual student.

In accordance with the findings on individual differences from the neuroscience's, new learning environments provide the right level of support and challenge in three ways.

First, they provide multiple means of representation. This means that instructional designs assume that there is little value in a single canonical representation of the information in any particular task or problem. Instead, new designers will assume that to provide basic access for some students (e.g. for students who are deficient in one modality or other, like a student who is blind), and multiple routes to meaning for all students (e.g. representing a math concept both in text and graphically) it will be both necessary and preferable to provide multiple representations of meaning.

Second, they will provide for multiple means of expression. This means that instructional designers will decrease their insistence on a single mode of communication from the student as the basis for expression or evaluation. It will be routine to assume that while many students will write (or type) their essays, there will also be alternatives that involve rich mixes of writing, illustrating, speaking, video-making, and drawing. The method of evaluation will suit the task and the means. Students will be required to meet a higher standard of expressive literacy—knowing in what contexts (for which purposes and for which audiences) to use text, images, sound, video, or combinations of media. Evaluation will be sensitive to purpose, audience, and the strengths of the learner. The creative expression of students with motor difficulties will not be evaluated via handwritten assignments.

Third, the new designs will provide multiple means of engagement. Most students are often unengaged or bored in school. There is no single solution to this problem because of the range of individual differences—there are many different reasons for their lack of engagement, not one. Students with disabilities, as usual, highlight the issues. The same design which would likely engage a student with ADHD (a high degree of novelty and surprise, for example) would be absolutely terrifying (and thus disengaging) to a student with Asberger's Syndrome or autism. New designs will be cognizant of the centrality of motivation in learning, and of the individual differences that underlie motivation and engagement. As a result, and given the flexibility of new media, they will provide alternative means of engagement—more novelty and surprise in the learning environment for some students, less for others, for example.

These flexible designs are called *Universal Designs for Learning*, and while initiated to meet the needs of students with disabilities and those with special talents, they are ultimately more effective with all kinds of learners.

NEW TECHNOLOGIES THAT ARE CHANGING OUR CONCEPT OF ASSESSMENT

In traditional assessment, the *outcomes* of learning are measured—the number of science facts recalled, the percentage of words spelled correctly. The interactive capacity of new technologies allows us to create dynamic assessments that measure not just the outcomes but the processes of learning. In so doing we will be able to understand what kinds of strategies a student is following, what kinds of strategies or approaches are lacking, what aspects of the task environment bias the student toward successful or unsuccessful approaches, and what kinds of additional strategies might best match their learning style.

Most important, the new technologies allow two-way interactive assessments. With these technologies we will be able to create learning environments that not only teach but also learn. By distributing the intelligence better between student and environment, the curriculum is able to learn about the student (their individual strengths and styles) and keep track of the successes and failures of its own methods. The result is a curriculum that becomes smarter, not more outdated, over time.

Finally, dynamic assessments will be universally designed. By providing a full range of customizations and adaptations as a part of assessments, we will be able to accurately evaluate student performance and the processes that underlie that performance. The accuracy will come from the capacity to evaluate performance under varying conditions—ranging from conditions where the student's performance is constrained by barriers inherent in specific modes of representation, expression, or engagement, to conditions where appropriate adaptations and supports are available to overcome those barriers.

CONCLUSIONS

The result of new technologies will be a re-centering of the core agenda of schools on learning instead of content. This will be fostered by advances in our understanding of what learning really is, how diversified it is, and which methods—such as Universal Design for Learning—are articulated and flexible enough to meet the diverse learning needs of all the students.

But the most fundamental change will come in our understanding of goals. The ultimate educational goals will no longer be about the mastery of content (content will be available everywhere, anytime, electronically) but about the mastery of learning. At commencement, we will graduate students who are "expert learners." They will know their own strengths and weaknesses, know the kinds of media, adaptations, strategies, and external technologies they can use to overcome their weaknesses and extend their strengths, and the kinds of colleagues who are likely to complement their own patterns of learning and performance. They will be prepared for a changing world, not a static one, prepared for the world in which they will actually live.

The particular benefit for students with disabilities is that the new technologies will, by necessity, recognize both the reality and the virtue of diversity. The technologies of the future will be more, not less, diverse, and they will engage many kinds of learners. The implicit goal of education will change from homogenization (all students pointed toward one outcome and measured by one yardstick) to diversification—identifying and fostering the inherent diversity among all of them, identifying new kinds of learning, new kinds of teaching, and new kinds of success.

Students with disabilities will have much to gain, and much to offer, in that enterprise.

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