An Assessment by Hoover Institution's Koret Task Force on K–12 Education

American Education in 2030

Curriculum Then and Now

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This was only Adam's third college reunion since graduating in 2005. The twenty-fifth, however, seemed important enough to attend in person, even though the technology supporting virtual reunions made meeting up with former classmates actually easier online than on campus. Still, he preferred the real thing to cyberspace when tossing back a few beers and reminiscing.

Many of his friends from college had, like him, gone into teaching, but he was one of the few still in the field twenty-five years later. So many had dropped out because technology had transformed education in the twenty-first century just as it had other labor-intensive industries in the previous century. One of Adam's grandfathers had run a family farm; one had been a navigator; and yet another was a printer. For all intents and purposes, none of those jobs still existed.

Teaching had survived, but the days of standing in front of a class of students, being a sage on the stage, were pretty much over.   That type of teaching position, now reserved for private schools for the rich, had succumbed to the triple whammy of unsupportable costs, the dramatic expansion of parental choice, and the marriage of cognitive science and instructional technology.

The nearly decade-long period of slow economic growth following the 2008 recession wreaked havoc on the revenues of state and local governments. After the string of federal stimulus packages ceased, those governments were forced to seek savings in the largest area of their budgets over which they retained control: public employees. Teachers were laid off or forced to take substantial salary reductions. At about the same time, the new choice provisions in the reauthorized federal Elementary and Secondary Education Act (ESEA) came into force. The new law required what we now take as given: open enrollment plans in public school districts with no default school assignments, interdistrict choice, nationally chartered virtual education providers, web-based information portals to the performance of education programs with respect to a variety of important student outcomes, and public funding for education programs determined by parental preference.

For a while, it wasn't clear whether this was going to result in anything other than the ability of parents to choose among options of declining worth. "I'll do my best to get my child into the least bad school" was the default choice strategy during time when schools were going about their business as they always had but with larger class sizes and less-well-paid teachers. That is when the innovations in curriculum and instruction that had been on the periphery of education reform for the previous twenty years began to take hold.

Those innovations, which we now label cognitive technology, married cognitive science and information technology. Cognitive technology, commonplace now, was a disrupter of the status quo in 2015, which is when Adam's cohort of teachers began to feel the pressure even though most had been teaching for ten years. The writing was on the wall: you had to either become an expert on the design and delivery of instruction through technology or become the equivalent of a hall monitor or a tutor for struggling students, with commensurate salaries. Adam's double major in computer science and psychology had positioned him well for his transformed profession; many of his former classmates with traditional education degrees weren't so fortunate.

In 2030 we are still in the early stages of the cognitive technology revolution in education. As we look to the future of curriculum, let us first take stock of the historical developments that got us where we are today.

Let's call the roughly 165 years of curriculum development before 2020 the age of paper. From *McGuffey's Reader* in the 1860s to the demise of the last of the great textbook publishing firms in 2020, the most common form of curriculum was a commercial textbook of which each student in a particular grade received a copy. Any technology was found in the ancillary materials and generally reflected the trailing edge of popular business tools of the day (e.g., overhead transparencies for use by teachers in the 1980s; electronic discussion boards for teachers around the turn of this century). These technology tools, however, were bells and whistles; the curriculum remained embodied in the textbook.

With the advent of the standards and accountability movement in the 1990s and the move to statewide adoption of textbooks in big states such as Texas and California, textbook publishers struggled to ensure that everything required by anyone was in the curriculum. The result was described by a critic at the turn of the century as curricula that were a mile wide and an inch deep. Even the best curricula lacked coherence, and the textbooks of the time became so thick that students developed muscle strains and joint problems from lugging them around in backpacks.

Notably absent in the paper-based curriculum were attributes that are now understood as state of the art. These include

1. Empirical and logical back mapping–This involves determining what the content of the curriculum should be at point t from the content requirements at point $t+1$, both through logical entailment and by determining the knowledge and skills at point t that predict favorable outcomes at point $t + 1$.

The process of back mapping from logical entailment is powerful in content areas that have an inherent sequential logic, the best cases being mathematics and musical performance. The ability to carry out mathematical operations with fractions, for example, entails fluency with whole-number arithmetic. Curriculum design based on logical entailment has a long history, but until about ten years ago it depended on the intuitions and deep knowledge of content experts. For example, expert mathematicians structured the curriculum sequence that students were to follow to prepare to take algebra. The breakthrough that has allowed logical back mapping to achieve its present power and its extension to the sequencing of topics at the level of individual lessons (called micro back mapping) came from the effort to program computers to meet the performance expectations of students at particular points in a curriculum sequence. This has not yet succeeded in creating machines that are intelligent enough, for example, to solve consistently the real-world mathematics problems that can be mastered by an advanced student in eighth-grade algebra. However, the programming endeavor, which has been successful in mimicking successful human performance on more routine mathematics problems, required detailed maps of the logical entailments of a successful performance at each stage of task completion. These logical entailments began with the intuitions of content experts but were automatically revised by the learning machines themselves as they attempted to solve the tasks in front of them. This has given us a detailed specification of the scope and sequence of knowledge and skills that are entailed by many of the performance outcomes expected of students in the school curriculum.

The process of empirical back mapping began with research in the 1990s to identify the preschool prerequisites for reading fluency in elementary school. Some of the findings were straightforward (e.g., the importance of early alphabet knowledge to later decoding skills). But some of the findings crossed domains, such as the importance of behavior and attention skills in preschool. Empirical back mapping has proven critical in such areas of the curriculum as history, in which logical entailments are weaker than in domains such as mathematics; in addressing horizontal effects across curriculum domains such as the reading prerequisites for successful performance in mathematics; and in addressing dispositional and motivation influences that map onto most curriculum domains.

Logical back mapping and empirical back mapping work best when combined. Logical back mapping identifies the content acquisition sequence that is necessary within a particular content domain; empirical back mapping identifies the many other factors that contribute to successful student performance.

2. Personalization–The curriculum of the paper age was largely lockstep: everyone in the same grade or class got the same book and was expected to go through it in the same sequence. Personalization was achieved largely by tracking students in different classes or course sequences. Thus the honors track might offer more advanced courses than the standard college prep track; students could also self-select into an advanced placement calculus class or a history course. But whereas education was personalized in the sense that different students had different courses on their transcripts, within any single course it was still the same book and the same sequence for every student. Technology began to change this about twenty-five years ago by providing teachers with periodic assessments of the status of individual students, accompanied by suggested activities to address areas of individual weakness. The development of back mapping and the shift from teacher- to software-guided instruction pushed us from those primitive forms of personalization to what we have now: students moving at dramatically different paces and sequences through a curriculum until they have demonstrated mastery of various way points and end points.

3. Cognitive science–In the cognitive science revolution in curriculum and instruction, much of the pedagogy and some of the curriculum content are informed by findings in the cognitive sciences on how people best learn. The cognitive and neurological sciences experienced an explosion of growth and discovery during the last quarter of the twentieth century, and they continue to be at the forefront of advances in the basic sciences today. What changed at the beginning of the century was a significant investment in research at the federal level in the cognitive science of education. This enticed cognitive scientists to study student learning in authentic education settings and to address questions of value to educators and the general public. Large numbers of cognitive scientists took the bait. For them the days of doing research on artificial tasks of short duration with undergraduates as subjects were over. They began instead to study such things as how prerequisite skills affect the ability of middle school students to succeed in an algebra, how the degree of difficulty in formative assessments affects long-term learning, how to use error patterns in student responses to decide on the next step in instruction, how to best balance the time students spend reviewing material versus being tested on it, and so forth. The neuroscience development of brain-imaging sensors so small, nonintrusive, and sensitive that they could monitor learning in real time was quickly taken up by cognitive scientists working in education. By 2020, the first practical applications of neural imaging had been developed to drive the sequencing of curriculum content and pedagogy for individual students. This led to the development of new instructional modules wherein learning is assessed by the degree to which requisite neural changes have occurred in the brain.

A related development was the growing knowledge of how and when to use social agents to motivate learning. The Internet-based group interactive games that gained a strong hold on the leisure time of adolescents around 2005 turned out to be the platform for the web-based social supports for student learning that are prominent today. The distinction between interacting at a distance with a real person and an entirely software-produced and -directed avatar began to blur as people chose to hide online behind digital representations of themselves and as the ability to program and realize humanlike behavior online grew more sophisticated. The friends students interact with online today in the context of academic tasks are as likely to be machine representations as the real thing.

4. Information technology–The previously described developments in back mapping, personalization of curriculum, and the cognitive science of instruction occurred hand in glove with advances in information technology. The ability to deliver curriculum and instruction through virtual environments is why many buildings that were once public schools have become access points for information technology environments that are still too advanced and expensive to be deployed in residences. Students now go to these buildings to access the technology and to meet others in the public spaces, not to sit in classrooms.

5. Micro impact evaluation–The large-scale randomized trials of curriculum products that were the rage in education policy through 2015 created an appetite among policy makers for reliable evidence on which products worked best and a market among consumers of education for effective products and approaches. Both the appetite among policy makers and the market among consumers have grown. But the developments described above that led to the death of the curriculum textbook also eliminated the motive to determine the impact of a particular curriculum. To the extent that each student was receiving a personalized curriculum, there was no single product to be evaluated. What we evaluate today is the effectiveness of particular approaches to transmitting a skill or knowledge set as it occurs at a given point in the curriculum back map. Hundreds to thousands of such micro instruction opportunities exist within a given curriculum. Consider, for example, an elementary school-level student's confusion over comparative descriptors such as "fewer," "about the same as," and "much more than." Micro impact evaluations can examine the relative effectiveness of different approaches to dealing with such confusion. Because instruction in the curriculum is delivered online to thousands of students working asynchronously, the evaluators can substitute a new or tweaked instructional module to a randomly chosen subset of students and determine, in close to real time, whether students in general or students with particular characteristics progress more smoothly through the new module than the old one. The success of the new or revised module is expressed in savings in time and errors and sometimes in imaged changes in brain function.

Adam was pleased to have been promoted to a position in his school district in which he was responsible for the history content at the high school level. He spent most of his time selecting and adapting technology and software to the goals of the district and the needs of students. He rarely stood in front of a class of students, but then nobody else did either. He was still attracted to that role. But he imagined that his grandfather, the navigator, also bemoaned the invention of the GPS and missed the days when the fate of the ship depended on his skills in determining its location on the globe. Because of the GPS ships rarely crash into the rocks; because of cognitive technology students rarely failed to learn the core content of the curriculum. A college reunion was an appropriate place to reminisce about the good old days of education, but Adam knew that students were far better off today.

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