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Thomas Tolstrup – Two students using a tablet computer in class.

Using Technology to Personalize Learning and Assess Students in Real-Time

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In 1915, famed educator John Dewey wrote a book entitled Schools of Tomorrow in which he complained that the conventional public school "is arranged to make things easy for the teacher who wishes quick and tangible results."[1] Rather than fostering personal growth, he argued that "the ordinary school impressed the little one into a narrow area, into a melancholy silence, into a forced attitude of mind and body."[2]

In criticizing the academies of his day, Dewey made the case that education needed to adopt new instructional approaches based on future societal needs. He claimed that 20th century schools should reorganize their curricula, emphasize freedom and individuality, and respond to changing employment requirements. Failure to do so would be detrimental to young people. In one of his most widely-quoted commentaries, Dewey predicted that "if we teach today's students as we taught yesterday's, we rob them of tomorrow."[3]

Writing nearly a century ago, it would have been inconceivable for him to envision the current world of electronic resources, digital textbooks, instructional games, interactive blogs, and social media. Yet his basic message remains highly relevant today. If schools don't re-invent themselves to engage students and train them for needed areas, it will be difficult for the United States to compete in the global economy.

Imagine schools where students master vital skills and critical thinking in a personalized and collaborative manner, teachers assess pupils in real-time, and social media and digital libraries connect learners to a wide range of informational resources. Teachers take on the role of coaches, students learn at their own pace, technology tracks student progress, and schools are judged based on the outcomes they produce. Rather than be limited to six hours a day for half the year, this kind of education moves toward 24/7 engagement and learning fulltime.

In this paper, I examine new models of instruction made possible by digital technologies. Pilot projects from across the country are experimenting with different organizations and delivery systems, and transforming the manner in which formal education takes place. By itself, technology will not remake education. Meaningful change requires alterations in technology, organizational structure, instructional approach, and educational assessment.[4] But if officials combine innovations in technology, organization, operations, and culture, they can overcome current barriers, produce better results, and reimagine the manner in which schools function.[5]

Personalized Learning

Mark Schneiderman, the senior director of education policy for the Software & Information Industry Association, spoke at a recent education symposium and said that "the factory model that we've used to meet the needs of the average student in a mass production way for years is no longer meeting the needs of each student."

Instead, he called for education changes that would recognize the enormity of the information changes that have taken place in American society. In today's world, he claims students "are surrounded by a personalized and engaging world outside of the school, but they're unplugging not only their technology, but their minds and their passions too often, when they enter into our schools."[6]

This point is echoed by Professor Daphne Koller of Stanford University. She teaches statistics through interactive online modules. There are video pauses and pop-up quizzes to gauge student progress. This frees up class time for Socratic-style instruction based on questions and problem-solving. She says "we teach classes in higher ed the same as the past 400 years. We are constrained by the number of students and classrooms, yet we are teaching due to constraints that are no longer relevant."[7]

Sticking to a 20th century production model makes little sense when there are 21st century technologies available that enable different instructional approaches and delivery systems. The key for educators is to figure out how to use digital technology to engage and instruct students. We need to determine ways to speed up technology adoption and extend it into the learning process in effective ways.

Psychologist Howard Gardner noted many years ago that there are seven different types of intelligences: linguistic, logical-mathematical, musical, kinesthetic, spatial, interpersonal, and intrapersonal.[8] Formal education that focuses merely on intellectual ability based on I.Q. tests is going to miss the artistic, cultural, spatial, and emotional intelligences that exist in many people. According to Gardner, "seven kinds of intelligence would allow seven ways to teach, rather than one."[9]

Wired classrooms and electronic instructional sets build on Gardner's insight by letting pupils learn at their own pace. Personalization makes education more adaptive and timely from the student standpoint and increases the odds of pupil engagement and mastery of important concepts. It frees teachers from routine tasks and gives them more time to serve as instructional coaches and mentors for students.[10]

New media specialist Mimi Ito of the University of California at Irvine explains that, "the ability for deep inquiry, to navigate complex systems, the ability to get good at something from a demand-driven perspective that fosters a sense of agency and efficacy, to know how to make things, to mobilize socially and politically [should come from] a 21st century learning environment."[11] We have the tools for this type of educational innovation, but it has been difficult for mainstream schools to embrace new models of education.

Rather than featuring rigid time schedules and annual grade promotion with minimum mastery of skills and concepts, it puts students in control of their learning pace. Time-wise, it is flexible and gives students access to instructional material around the clock. In conjunction with teacher guidance, students undertake lessons based on their preferred learning approach. As they master key concepts, they advance to higher skill domains.

The U.S. Department of Education's "National Educational Technology Plan" sets forward the goal of using technology "to provide engaging and powerful learning experiences, content, and resources and assessments that measure student assessment in more complete, authentic, and meaningful ways."[12] It points out that "technology-based learning and assessment systems will be pivotal in improving student learning and generating data that can be used to continuously improve the education system at all levels."[13]

Already, we are seeing certain schools move forward with an agenda based on personalized learning. The New York City School of One represents a novel case of digital innovation in the classroom. Rather than having a single teacher for a specified group of students, this school employs team-teaching targeted on individual students. Each pupil gets a daily "playlist" with a variety of instructional activities geared to their needs. This can include time with a teacher, an online tutorial, a video game, or various types of electronic resources. Progress is tracked electronically and students move to the next level when they have demonstrated appropriate skill mastery.[14]

This approach puts students at the center of the education process. Their daily activities are based on what they need to learn and which approaches deliver the best results for them. Pupils can receive instruction either one-on-one or in small groups of students. With computers tracking how they make progress, instruction can speed up or slow down, depending on the needs of that particular individual. Special needs students can get additional time and attention, while gifted pupils can pick up the pace and move quickly to more demanding exercises.

Student customization represents an important advance because it recognizes that pupils come from different backgrounds, interests, and ability levels.[15] Chris Rush, the co-founder of the school, argues that "the key cultural mindset that changes with School of One is not the technology, but the way in which the program thinks about student progress. The approach attempts to meet each student at her current level and create as much growth as possible."[16] As a School of One student put it, "If I don't understand something, I can try and learn it in a new way and take my time. I don't have to learn it the same way everyone else does."[17]

Another promising program is High Tech High, a series of 11 public charter schools in Chula Visa and San Diego, California. Its schools focus on "personalization, adult world connection, and common intellectual mission."[18] They work with inner city high schools that employ "school-to-work" strategies based on internships, field work, and project-based assignments. Students are given a "staff advisor" who coordinates the individual's personal and professional development and works with family members. School members have access to laptops, networked classrooms with fast broadband, project rooms, and exhibition spaces.

In these charter programs, teachers take on the role of coaches. Instructors work in teams and devise integrated student projects based on collaboration and engagement. Rather than being lectures, the courses focus on information

delivery through a multitude of approaches. Teachers define their tasks as coaching students up the performance ladder, with pedagogy adapted to the learning styles of individual pupils. There is no "one-size-fits-all" approach to instruction. This helps students master concepts at their own speed and in their own way.

Pupils have a mandatory work commitment in which they devote a semester interning in a local business or government department. School officials encourage them to have lunches with adults with a record of accomplishment and to participate in "shadow" programs with outside mentors. This integration of work with school helps to keep students on track and focused on what they want to do after graduation.[19]

Another example of a new learning paradigm is the for-profit K12 company. It enrolls around 81,000 young people in 27 different states in online education. Students "study on their own, clicking on lessons, doing exercises, taking tests, with teachers available by e-mail and phone for support." In this kind of independent environment, pupils must be self-motivated and able to work on their own. Parents play the role of instructional coaches and students learn at their own pace.[20]

According to Chip Hughes, executive vice president for school services at K12, it is important to measure the intellectual growth of students. Since the organization deals with students who have difficulty in traditional schooling, they sometimes do not score well on standardized tests or graduation metrics. Analysts have to keep in mind the disadvantaged nature of their clientele and particular difficulties they have. If students who have problems in conventional classrooms display progress in mastering material, that is clear evidence of educational effectiveness.[21]

In New York City, Mayor Michael Bloomberg's Innovation Zone focuses on customizing student learning through digital technology. Armed with $50 million in federal money based on the U.S. Department of Education's "Race to the Top" program and $15 million in private investment, school officials are experimenting with a number of personalized approaches at schools across New York City. By 2014, the Innovation Zone program will include 400 schools.

At the Washington Heights Expeditionary Learning School, for example, City pupils can go from one grade level to another as they master particular subjects. The East Bronx Academy for the Future is providing computers for every student so that each can work at his or her own speed. The PS 154 Harriet Tubman elementary school is emphasizing personalized digital learning in the areas of math and languages.[22]

News Corporation's Wireless Generation emphasizes reading, writing, and data management programs.[23] Its Burst Reading early literacy intervention initiative seeks to develop skills through short, interactive lessons. Instructors monitor reading activities and employ data diagnostics to guide student progress. Its data systems allow schools to compile, analyze, and report school data so that administrators can evaluate how things are going at various levels of the system

and what instructional adjustments need to be made.

Some teachers elsewhere have developed Facebook applications for personalized learning. They are using social media to post comments, get reactions from students, set up meetings, and express views about the class. Research conducted at a private liberal arts university found that for courses set up in this manner, students averaged an hour per day accessing the Facebook Learning Management System. Instructors discovered that students responded almost immediately to messages about the course and that pupils "engaged more in questioning through Facebook messages directed to the instructor than asking them verbally in the face-to-face classroom."[24]

Empirical Evidence on Effectiveness

The problem with past efforts at education reform is that many of them focus on raising performance, but do not alter the manner in which instruction is offered.[25] The basic structure of the classroom stays the same with teachers presenting information in conventional ways and students taking periodic tests to demonstrate mastery. With little effort to alter the fundamental model by which education takes place, it is difficult for students, teachers, or administrators to perform better or raise levels of school achievement.

Many academic studies have found that students do not retain information very long. For example, a university research project that had students retake a course's final examination after the end of a course found a significant drop in performance just one semester later.[26] College students were not able to retain information over the period of a few months.

With personalized learning in its infancy, it is hard to find systematic data concerning effectiveness. Randomized, double-blind evaluations are virtually nonexistent. Detailed quasi-experimental studies with large N's are not common. However, there is preliminary research on particular types of personalized education instruction and how it affects student learning and achievement.

One project undertaken in 2009 by the U.S. Institute of Education Sciences looked at computer-assisted instruction and its impact on student test scores in math and reading. Examining a number of different products, the study found improvements in learning engagement, collaboration, participation and communications for specific software, but mixed results for basic skills and higher-level thinking.[27]

In the first year of usage, the results generally were not statistically different in terms of the impact on achievement. But by the second year of usage, there were improvements in reading and algebra comprehension for the 3,280 students analyzed. This suggests that computerized instruction needs to be maintained over a period of time to generate appreciable gains in student performance.[28]

This assessment, though, was limited to analysis of particular software products. The 77 schools in 23 different districts studied were traditional schools

with standard curricula supplemented through computer-based instruction. As such, the results are not definitive in terms of the application of transformative models of personalized education.

There has been analysis of specific classroom technologies. For example, a study of an "intelligent tutoring system" based on computers found improvements in student knowledge "when classes are well-planned, well-taught, and matched to student needs."[29] As with many areas of personalized educational attainment, the quality of the teaching mattered as did the tailoring of instruction to individual students.

A related study of an intelligent tutoring system called the Help Tutor found that when incorporated into the Geometry Cognitive Tutor, it "improved students' help-seeking behavior while learning geometry." Pupils mastered geometry faster and more effectively than in the case of traditionally-based instruction methods.

Based on these results, the authors argued that "knowing when and how to seek help during learning is a key self-regulatory skill" and that this kind of electronic resource "helps students learn more effectively."[30] The online tutoring tool aids learning by monitoring how students approach math problems dealing with the geometric characteristics of circles, providing relevant hints, and giving them access to a detailed knowledge base. It allowed students to avoid common errors and coached them along the path to solution.

A project of a "blended" learning approach in a large-enrollment psychology class at San Diego State University found improved academic performance and student satisfaction from online help tools. The authors compared student performance in traditional lecture presentations versus lectures plus participation in a Wimba Live Classroom. The latter were online sessions that included mini-lectures, instructional demonstrations, videos, and pop-up questions that evaluated student learning and satisfaction levels. In general, the blended presentations out-performed traditional lecture delivery. It had higher student grades and better course evaluation ratings.[31]

Collaboration represents a virtue in the online world. Rather than working one-on-one, technology enables students to collaborate with one another and work with a range of interactive, instructional resources. This can include teachers, parents, peer tutors, volunteers, and other interested individuals. Turning education into a social event with regular feedback and challenging assignments helps to spur student achievement.

An organization that is undertaking innovative work on education collaboration is the company ePals and its affiliate, In2Books. The former focuses on collaborative and self-directed education, while the latter is an e-mentoring program emphasizing reading, writing, and critical skill development in grades three to five. That program matches students with "adult pen pals" who read books in five different genres (fiction, biography, folktales, social studies, and science) and exchange letters about those volumes. The correspondence covers not just what students comprehend from the book, but how students write up their impressions and analysis.

Research undertaken on this program shows improvements in reading comprehension. For example, William Teale and Linda Gambrell analyzed Washington, D.C. student reading achievement during the 2003-2004 school year.[32] Washington is a particularly compelling case because of high poverty within the District and a challenging home and education environment. The authors compared Stanford Achievement Test results across several categories of students: classrooms where teachers had used the program for two or more years, ones in the first year of implementation, and those which did not rely on the reading program. In each of the three grade levels studied (two, three, and four), they found that students participating in the program scored significantly higher than those not in the program.

In reviewing reasons for this positive impact, researchers noted that four factors were important. This included reading "high-quality, age-appropriate, appealing books", repeated reading and discussion of the book, following a writing process that emphasized drafting, revising, and editing the book reviews, and employment of regular professional development for teachers.[33] Having challenging, authentic, and persistent work made the greatest difference for students. The use of a "learning community" based on collaboration correlated highly with success.

Another assessment project looked at the organization's pen-pal program for reading, writing, and discussion based on 219 elementary students who participated in the study. Students read books, discussed the material with an adult pen-pal, and participated in small group discussions about the material. A comparison of pre- and post-program activities revealed that the pen-pal activity positively affected student motivation, group interactions, and discussion participation. Study members reported improvements in their motivation for reading, the quality of their interactions with other students, and engagement with class discussions.[34]

Other projects have found that social media are especially helpful on subjects that students find embarrassing, such as eating habits. A British project on "personal inquiry learning" with high school students found that mobile software was very useful in educating them about healthy eating. Students used mobile devices to record their daily consumption of carbohydrates, protein, fats, fiber, and water. This information was imported into a data base and compared graphically to recommended nutritional intake levels. In conjunction with student's personal data collection, teachers integrated material on health, science, and diet management over a series of nine lessons.[35]

In following this regimen, teachers discovered that students increased their diet and health knowledge by 20 percent from beginning to the end of the course. They also gained more detailed knowledge about science and statistical methods of data collection and analysis. Instructors felt that the learning approach helped to integrate classroom and home education and gave students a better sense of scientific inquiry on a topic (healthy eating) that is challenging for young people to understand and implement in their personal lives.

Real-Time Student Assessment

Since the enactment of the No Child Left Behind legislation in 2001, educational assessment has focused on annual student tests. Young people across the country in grades three through eight and high school take standardized tests measuring aptitude in reading and math. The results of these state-administered exams are compiled and released in aggregated form to parents, teachers, reporters, and policymakers. The test results generate high levels of media coverage, and have become a major measuring stick both in terms of individual classroom performance as well as evaluations of overall school achievement.[36]

At one level, these exams represent useful ways to evaluate student performance. They allow public officials to compare schools, districts, and states on common metrics, and judge how much progress has been made compared to past years. By measuring performance at multiple levels, the tests help public officials judge the impact of instructional activities. This makes it possible to see how different places are doing and what kind of advances are being made over time.

But in other respects, evaluation based on standardized testing is seriously flawed.[37] These examinations take place only once a year so therefore provide just a single snapshot during the course of 12 months. Ideally, assessment would be more frequent so that teachers, parents, and administrators could see how performance improves at various points during the school year.

In addition, standardized tests are not linked to particular educational materials, so it is hard to know which instructional sets produced the best results.[38] Educators want to know which curriculum works, which instructional techniques are most effective, and which lessons get through to students. Having standardized test results once a year does not provide nuanced information because you never can be sure which activities during the course of that entire year produced specific test results. Was it a new curriculum that got introduced, new teaching techniques, money allocated to technology, or a particular subset of students who took the test?

This inability to distinguish "cause and effect" makes it impossible to evaluate the reasons behind particular test results. Teachers, parents, students, and policymakers need more regular feedback on a range of assessment tools so they can make informed decisions regarding school operations and budgetary allocations. Better information would help them judge what works in the classroom and what is not very effective.

Digital technologies create opportunities to measure student performance in a much more nuanced and multi-faceted manner than previously was the case. No longer are teachers limited to standardized annual examinations or periodic classroom tests. Instead, they have the chance to provide feedback at virtually every step of the learning process and use this regular evaluation to gauge progress toward educational objectives for individual pupils.

Through online means, teachers can look not just at what concepts students

have mastered, but how much time they have spent on readings, how long they retain particular bits of information, what educational materials produced the best concept mastery, and behavioral and cognitive information relevant to academic performance. They can follow the learning process in order to determine what is the best instructional plan for particular people.

One way to do this is through audience response systems. Classroom students are given electronic clickers which allow them to answer questions posed by the instructor in real-time and have their individual and overall class responses tabulated. The teacher or professor can project the aggregated answers and show students how the class as a whole responded to particular inquiries.

In an analysis of these devices, Professor Terence Hancock of the University of Louisville examined clicker use for testing purposes in two large management classes. He compared test scores before and after introduction of clickers. He found that "test scores jumped 13% from 56 to 63 with clicker use" during class time.[39] They increased another 14 percent to 72 points when clickers were used both during class and on tests.

Clickers are helpful from a learning standpoint because they provide instantaneous feedback to students and faculty. Each benefits from the real-time nature of the educational assessment. Instructors use information derived from student responses to gauge how effective their information presentation is and how quickly material is being learned. Students meanwhile receive quick feedback on whether they are coming up with correct answers to specific questions.

Transforming the assessment process represents a major way to improve learning and drive education change. Just as No Child Left Behind leads instructors to "teach to the test," real-time assessment encourages teachers to incorporate a broader array of assessment dimensions into the classroom and provide feedback on what is effective. This information helps them tailor instruction to individual students and enables pupils to see what works for themselves.

Measuring Concept and Skill Mastery

School systems place a high priority on formative assessment, meaning feedback designed to improve the learning process. This includes measurement of discrete subjects, such as concepts mastered, skills realized, and time spent on particular assignments. Feedback typically is embedded in the instructional process so that students and teachers get real-time results on what is being learned and can monitor overtime performance.

Even in the era before the Internet was firmly entrenched, research suggested that formative assessments had a significant impact on knowledge acquisition. Paul Black and Dylan Wiliam's review of 250 research projects concluded that

formative assessments produced a "powerful effect on student learning."[40] It represents a way to gauge effectiveness on key educational objectives.

The virtue of digital technology is that it enables assessment of each piece of the learning process. Students spend considerable time in the online world. They search for information through the Internet. They interact with computer-based instruction. They have online tutorials and electronic mentoring. Through online devices, it is possible to increase the range of skills and concepts assessed, and the manner and frequency by which these evaluations are undertaken.

With the advent of computerized instruction, scholars argue that the specific type of feedback matters. For example, David Nicol and Debra MacFarlane-Dick outline seven principles of effective feedback. They include clarifying what good performance is, facilitating self-assessment in learning, delivering high quality information to students, encouraging peer dialogue around learning, encouraging positive motivations, showing how to close gaps between current and desired performance, and providing information to teachers on effective feedback.[41]

It is possible to take these principles and use them to evaluate learning in more detailed ways. Vincent Aleven and his colleagues at Carnegie Mellon University describe ways to run controlled experiments through Intelligent Tutoring Systems. The latter represent tools through which professors can develop online tutorials in areas such as chemistry and physics, and compile pre-test and post-test assessments plus detailed records of interactions between students and electronic tutors.

These types of computer tutorials can evaluate problem-solving approaches and provide feedback along the instructional path. The system sends error messages if the student follows an incorrect approach and provides answer hints if requested by the student. Instructors can get a detailed analysis not just of whether the student reached the final answer correctly, but how they solved the problem.[42]

In order to expedite more detailed assessment, a number of business schools have moved toward online, real-time case studies as a means of instruction. These studies rely on the Internet to bring real, live cases to the classroom by presenting students with specific companies and asking them to follow and evaluate their decisions over the course of the semester. At various points in time, students have to assess how the company handled particular problems and what the corporation could do to perform better and improve business operations.

Research by James Theroux of the University of Massachusetts at Amherst found that this approach "engages and satisfies students at a higher level than do average courses and presents a more realistic and integrated view of business decision making."[43] A clear majority of pupils preferred the online over a traditional approach and felt the course materials were very applicable to real life. The cases helped faculty assess the degree to which students grasped management principles and gave them an opportunity to apply student feedback based on actual corporate experiences.

WebQuest is another online activity that teachers employ to send students to the web to find information or solve particular problems. It is designed to train pupils in skills of information acquisition and ways to evaluate online materials. Students are given particular tasks and use the Internet to seek and evaluate alternative sources of information.

A detailed survey by scholars Robert Perkins and Margaret McKnight of 139 teachers who attended an instructional technology conference devoted to WebQuest found that most instructors believed students were engaged with these types of assignments because they enjoyed their collaborative and interactive nature.[44] As opposed to looking for general Internet information on their own, students had to talk with one another to fulfill the assignment.

The team-based and collaborative nature of the software meant that students had to solve problems and engage in critical thinking while working with other individuals. As long as the exercises were well-designed, teachers reported that they contributed to student learning and enhanced the educational process. Their interactive qualities helped pupils learn how to evaluate electronic materials and gave the faculty detailed tools by which to assess student mastery of course material.

Virginia Commonwealth University have developed an e-assessment tool for faculty to gauge student performance. The software compiled information on how students completed assignments and what barriers and/or obstacles they had to overcome. Instructors were given detailed feedback on what students were learning and how they mastered the material.

In measuring faculty adoption, though, officials at the University of Nebraska found that only about half of campus faculty actually used the available technology. In undertaking a survey of professors to determine why only some used it, researchers found a number of interesting results.[45] Adopters tended to perceive a higher level of "result demonstrability" than non-adopters. They felt the results of the e-assessment system were apparent to them and they had no difficulty in explaining why the program was beneficial. Non-adopters tended to see the software as a distraction from research and believed the administration was forcing them to do something they didn't want to incorporate.

In documenting these results, this study echoes a project from overseas. A survey of 239 teachers at the National Institute of Education in Singapore found that teacher attitudes towards new software were primary determinants of technology acceptance. Individuals who perceived technology usefulness and ease of use were more likely to adopt new approaches than those who did not. Teacher attitudes towards computers represented a big determinant of actual technology usage.[46] Educators need to be especially sensitive to the teacher role in pedagogy because they play a crucial role in determining whether particular reforms succeed or fail.

Needed Policy Changes

One of the greatest challenges in the adoption of education technology is outmoded policy regimes. In general, school operations lag the opportunities created by technology innovation. It is possible to teach students in a variety of different ways and through alternative structures, but current policy in many states prohibit or impede many types of new instructional approaches.

Several policy changes are required in order to encourage the adoption of personalized learning approaches. Dr. Mimi Ito notes that:

> We've always known that we learn a whole lot outside of school. But there is increasingly a culture gap between the modes of delivery. A gap between how people learn and what is taught. The whole methodology always has been the perception that classrooms are boring, but it's worse now. Students ask, 'why should I memorize everything if I can just go online?' There's a growing alienation. Teachers are just as aware of it as the students."[47]
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> Continuing, she points out that "schools currently aren't preparing kids for life. If we allowed the boundaries of schools to be more porous to the outside world, to involve life prep rather than test prep…. [Currently, students follow] a narrow pathway to learn basic skills that move them up the ladder, and if you get up the ladder then somehow you'll be prepared to be an adult and have job relevant skills…. We are clearly encountering a crisis because of the fact that there's been a narrowing within the educational institution."[48]

Many secondary schools use the "Carnegie Unit" and colleges use the "Student Hour" to monitor student progress. Early in the 20th century, educators adopted these "time-based" approaches that mandated students must have at least 120 hours of classroom time over the course of a year to master particular subjects. In addition, four years was specified as the appropriate length of high school and bachelor's degrees in college. Most American schools continue to employ this framework to structure the curriculum and daily classroom schedule.[49]

The problem with time-based approaches is that they equate time spent with subject area knowledge. They assume that if students have enough face-time with instructors on a particular topic, most of them will meet minimum performance standards at the end of the course. However, this logic is flawed at both ends of the education spectrum. There are some students who need more time to master specific subjects and there are others who can learn the material in a shorter period of time.

Susan Patrick, the president and chief executive officer for the International Association for K-12 Online Learning, noted that "the biggest barrier is the Carnegie unit, seat time….We are basing our entire system on the number of minutes within four walls….Moving to a competency-based system, away from

seat time, is an essential condition to getting to personalized learning."[50]

She suggests that a "mastery-based" approach would work better than one based on time. Right now, education funding is determined by the "average daily attendance". This means that schools that incorporate online learning or have students who can master material in less time than required by seat-time measures, are penalized financially for these innovations. They end up with fewer budgetary resources even though their systems may make more efficient use of education dollars.

With digital technology, learning can be personalized to the individual and performance evaluated in real time. This means that accreditation agencies should provide schools and universities with more flexibility in use of classroom time and not rely just on formalistic measures of student performance. Students can be promoted when they learn a subject as opposed to when they have sat a minimum number of hours in a seat.

Such a system would need more flexible teacher roles, better financing of classroom technology, and regular evaluation and assessment so school officials know what works. Personalization makes sense only if there is documented evidence that students are learning the subject matter and making progress in various areas.

This is particularly the case at the level of secondary education. In general, higher education is ahead of secondary education in making use of innovative technology. The decentralized nature of higher education, the emphasis many professors place on innovation, the competition across schools for students, and the absence of a school board or school bureaucracy to slow progress have made a substantial difference across levels of the educational system.

Unless more schools adopt these digital technologies, they will be unable to track real-time student performance. School officials need to integrate their databases to enable the kinds of connected information systems discussed here. In order to create dashboards and website assessments, they should view their data information as a valuable resource that aids in planning and assessment.

The field of personalized learning clearly remains in the early stages of development. As noted by Professor Scott McLeod of Iowa State University, "the essential, core 19th century model of filling up someone's head like a bucket still holds very strongly."[51] But there are encouraging signs of possible advantages of personalized learning. Systems where students collaborate with one another, participate in the formulation of their own instructional plans, and engage with the learning community show considerable promise in terms of educational attainment.

The empirical evidence on effectiveness remains preliminary and impressionistic. We lack rigorous studies that demonstrate how and under what conditions digital technology aids education. But we know that blended or hybrid approaches show effectiveness on skill mastery and that young people report they are more engaged with digital than conventional approaches.

We require additional research to test hypotheses and document relationships. There should be further analysis of ways education personalization can help students master material and learn at their own pace. We need better information on how technology affects particular subgroups of students based on income, gender, and race as well as gifted versus special need students. Understanding the impact of technology in the education process is vital for charting the future direction of schools.

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