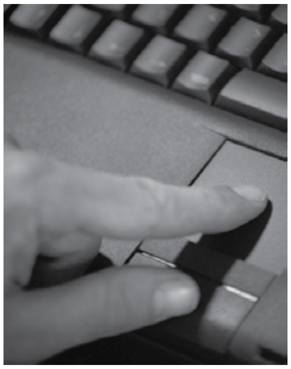

How New Technologies Have (and Have Not) Changed Teaching and Learning in Schools

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Abstract

Information technologies have reshaped teaching and learning in schools, but often not in ways anticipated by technology proponents. This paper proposes a contrast between technologies for learning and technologies for learners to explain how technologies influence teaching and learning in and out of schools. Schools have made significant use of assessment and instructional technologies that help promote learning for all students, whereas technologies for learners, such as mobile devices, video games, and social networking sites, are typically excluded from school contexts. The paper considers how these contrasting models of technology use will come to shape schools and learning in a pluralistic society. (Keywords: school reform, digital media, accountability policies, virtual charter schools, assessment)

Introduction: The Promise of Technology and Learning

Information technologies have always held great promise for transforming our teaching, thinking, and learning. The computer's capacity to construct symbolic representations for any given domain has already transformed how we think about knowledge work. In *The Mind's New Science*, Howard Gardner (1985) suggested that the emergence of the computer was at the heart of the cognitive revolution in psychology. Psychologists in the 1950s used massive, card-processing computers to create interactive symbolic simulations to develop and test hypotheses about complex cognitive processes. Research by computing has since been applied across the social sciences to create new avenues for investigation from economics to sociology and from meteorology to virology.

The advent of the personal computer promised to bring the same transformational power to K–12 classroom teaching and learning. Enthusiasts such as Seymour Papert (1980) predicted that computers would allow learners to construct and test hypotheses about complex systems. Introducing computers into schools, Papert argued, would radically change the relationship between teacher and student. Teachers would need to become interdisciplinary facilitators of student creativity, readily able to guide learning toward intended outcomes while creating legitimate space for experimentation. Computing would allow students to create and test knowledge claims. Computing would extend communication networks, provide immediate access to information, and facilitate new forms of creative expression. Papert's work ushered in a new era of expectations in which the computer might be allowed to transform the classroom just as it had already transformed the academic world.

Papert also saw that the transformational power of the computer would face an uphill battle (Papert & Harel, 1991). The forces of "instructionism" organized K–12 schools around passive disciplinary knowledge and encouraged passive learning processes based on knowledge absorption. The instructionist model suggests that schools were designed to control the learning experience, teachers are technicians who dole out knowledge, and students are judged according to how they achieve in terms of the instructional model. The instructionist model has proven remarkably resilient. Researchers such as Larry Cuban found that instruction in many schools looks shockingly similar to instruction 20, 50, even 100 years ago (Cuban, 1986; 2001). K–12 schools have reacted to new technologies in two ways—co-opting tools that reinforce existing practices (Powell, Farrar, & Cohen, 1985), or minimizing the threat of disruptive technologies though marginalization or banning (Christensen, Johnson, & Horn, 2008). It would seem as though Papert's dream about the transformative power of computing for learning has been derailed by the prevailing priorities of the existing school organizational model.

This paper will discuss the questions of whether and how technologies have influenced teaching and learning, and what paths are open (and closed) for future impact. We argue that technologies have fundamentally transformed schools—but not in ways anticipated by classroom technology enthusiasts. First, we consider how the potential of learning technologies has always been expressed at two levels: technologies for learning and technologies for learners. This distinction refers to the uses toward which technologies are directed. Technologies for learning support the interests of the technology designers. Designers select learning goals and build technologies that best guide users toward these goals. Technologies for learners, on the other hand, allow users to select learning goals and to choose the means that will best achieve their goals. Technologies for learning are instructor-directed; technologies for learners are client-directed. We suggest that, whereas technologies for learners have struggled to gain foothold in traditional schools (at least in ways that enthusiasts might have hoped), technologies for learning have proliferated wildly in schools. Second, we speculate on the future of technologies for learners and for learning by contrasting two emergent venues: virtual charter schools and fantasy sports. We argue that technologies for learners, often expressed through games, emphasize the agency of players, whereas technologies for learning focus on organizing resources to produce reliable learning outcomes. Finally, we describe how technologies threaten our current conception of learning while simultaneously opening up a new landscape of options for K–12 education.

How Technologies Have Shaped Teaching and Learning

The trends that guided 1990s approaches to technological change in schools were marked by two dominant trends. First, massive investment of public resources attempted to create universal access to technology in schools. Second, public research investments created high-profile examples of how to use the technologies for progressive instructional practices. Together these conditions were supposed to spark revolutionary changes in classroom practices. The direct consequence of these investments resulted in disappointingly meager changes in classroom practices (Cuban, 2001). The indirect consequence, however, was the development of a robust technology infrastructure to meet the demands of the high-stakes accountability policies of the 2000s.

Public investment in classroom technologies and innovative curricula. The promise of computing took the education world by storm in the 1990s. Schools spent increasing amounts of their discretionary funds on computers, networks, Internet access, and other digital technologies. The federal government alone invested more than $8 billion in educational technology from 1995 to 2000 (U.S. Department of Education [DOE], 2000). One report found that in 1998 alone, 2.7% ($7.3 billion) of all educational expenditures went to technology (Anderson & Becker, 2001). The ratio of students to computers in public schools dropped from 25:1 in 1988 to 5:1 in 2000 (Cuban, 2001; Twining, 2002). The percentage of public schools with Internet access rose from 35% in 1994 to 97% in 2000 (National Center for Educational Statistics, 2001). In the midst of this investment bonanza, a national committee called for at least a three-fold increase in public spending on technologies and related services (President's Committee of Advisors on Science and Technology & Panel on Educational Technology, 1997). The perceived role of technologies in the booming 1990s economy led to a seemingly irresistible mandate for the education community to remake schools as technology-driven institutions.

A second trend was to use public grant funding to spur examples of high-quality, scalable classroom technology applications. Becker and Ravitz (2001) argued that classroom teaching could change if teachers gained experience in using computers and became more committed to a progressive philosophy to instruction. The National Science Foundation and private foundations made significant investments in curriculum projects to promote a progressive approach to learning (Bruer, 1993). Constructivist math and science education projects, such as Vanderbilt's Jasper Woodbury math curriculum project (Cognition and Technology Group at Vanderbilt, 1997), the UC Berkeley Thinker Tools inquiry project (White & Frederiksen, 1995), and the Northwestern and University of Michigan's Learning Technologies for Urban Schools (D'Amico, 2005), developed innovative, technology-based curricular materials and opportunities for teacher professional development. These projects had significant impact on collaborating schools and teachers but modest reach beyond participating professionals. Bridging the gap between these progressive islands of innovation and typical school practices led reformers to call for widespread professional development opportunities to help integrate technologies into daily teaching practices (Office of Technology Assessment, 1995). Policy makers hoped that this combination of innovative materials and learning opportunities would catalyze the investment in technological infrastructure and result in widespread changes in teaching and learning (US DOE, 2000).

Despite the investments and the successful run of curricular innovations, the classroom practices of the 1990s and the early 2000s remained largely unchanged. Larry Cuban (2001) discussed how traditional teaching and learning practices persisted even in Silicon Valley schools, which were situated in communities thoroughly immersed in computing technologies. In most schools, students' computer use was restricted to 30–60 minutes per day in computer centers outside the classroom. Some classrooms had computers in the back of the room for supplemental learning activities, and only a few teams of teachers managed to integrate computers into everyday teaching. The most common student uses of computers in the classroom, according to a sample of fourth grade teachers, were playing math games or drill-and-practice software (National Assessment of Educational Progress, 2003). Access to technology did not lead to change, and even when teachers knew of innovative practices, they had difficulty applying new ideas into existing classrooms (Kleiner & Lewis, 2003). Not only did classroom practices remain unchanged, but applications that were implemented at scale, such as math and reading software products, also had little effect on student learning (Dynarski et al., 2007). The theory of action that emerged to guide technological innovation in the 1990s—developing infrastructure investment and innovative practices—did not spark widespread changes in teaching practices. From the classroom perspective, it seemed as though instructionism had won and Papert's dream would be unfulfilled.

The advent of high-stakes accountability. Computer use in schools did change in the early 2000s in response to a philosophical shift, but not in the direction of constructivism. The advent of standards-based teaching and high-stakes assessment made teaching and learning seem even more structured, more predictable, and less adventurous. The No Child Left Behind Act (2001) changed the landscape for school technology use. NCLB brought advocates for content standards together with proponents of high-stakes accountability to transform the expectations for U.S. public schools (Anderson, 2005). All students in grades 3–8 would be tested in core subject areas, and states would be required to make disaggregated data public to allow for comparison of achievement across student groups. Data-driven accountability created a demand for schools to improve student information systems, community outreach, and communication systems. Taken together, these technologies have transformed the administrative practices in schools and have led to unanticipated consequences for classroom teaching and learning (Burch, 2006).

Schools turned to information system technology to collect, manage, and analyze student learning data. Even in the 1990s, one study estimated that two thirds of school technology investments went into technical infrastructure (McKinsey, 1995). Burch (2006) described how this early investment in technological infrastructure led many schools to move from outsourcing data system capacity to implementing ambitious data systems and networks. The burgeoning private market for information technologies has supplied schools with products for data warehouses, querying tools, customizable databases, and parent and teacher communication tools (Wayman & Stringfield, 2006). State Web sites such as the Wisconsin Information Network for Successful Schools (http://dpi.wi.gov/sig/index.html), Minnesota Milestones (http://www.mnplan.state.mn.us/mm), and SchoolMatters.com provide unparalleled access to disaggregated student achievement and demographic information.

Data-driven instructional systems. State and local data systems gave schools abundant access to student achievement information. Prior to NCLB, researchers such as Richard Elmore (2002; Abelmann & Elmore, 1999) warned that schools did not have the capacity to make effective use of achievement information. In the early 2000s, school leaders scrambled to build internal capacity to turn access to achievement data into effective instructional decision making (Mandinach & Honey, 2008; Wayman & Stringfield, 2006). Turning assessment data into information that would help teachers improve instruction required that schools develop measurable and attainable achievement goals, identify performance gaps in current instructional practices, refine or reform instructional practices, and systematically test whether new practices addressed school-wide learning goals (Halverson, Grigg, Prichett, & Thomas, 2007). In other words, meeting the demand of high-stakes accountability has required schools to create or acquire benchmark systems to gauge the degree to which students are making progress toward mandated learning goals (Blanc, et al, in press; Perie et al., 2007). Holding classroom practices accountable to statewide measures of student learning meant that teachers would need to integrate standards-based diagnostic and summative assessment practices into their daily teaching practices (Hamilton et al., 2007).

How have classroom teaching and learning practices changed in response to data-driven accountability policies? Using information beyond classroom quizzes and tests to assess learning has led to distributed expertise networks in many schools. Halverson, Prichett, and Watson (2007) described how data use transformed a group of first grade teachers in a rural Midwestern school into a collaborative team. The school principal helped redefine a Title I teacher position into an early-grade reading specialist and collaborative teacher. The reading teacher would spend one to two hours a day as she rotated through the 4 first grade classrooms. Reading lessons involved breaking students into three learning groups—some ability leveled, others heterogeneously grouped. The reading teacher and the classroom teacher would each take a group for one third of the class; the remaining group would be engaged with independent learning activities. During her time, the reading teacher would use common reading and writing assessments to determine student progress through the curriculum. The teachers would meet together weekly to discuss assessment results to regroup students or reorganize the curriculum. As one teacher in the school remarked, "we are seldom surprised" by the results of the state test (Halverson, Prichett, & Watson, 2007, p. 22). In this case, although the collaborative teaching we observed was decidedly low tech, the changes were prompted by the school and district responsibility to produce results in the context of a high-tech, high-stakes data system.

It seems as though data-driven instructional systems represent a dystopian version of Papert's vision of how technologies would change learning. Papert saw computers as liberators of curricula, providing tools for students to construct complex, dynamic representations of mathematical and systemic processes. Teachers would become facilitators for student creativity. Disciplinary studies would give way to interdisciplinary investigation. Instead, accountability-based learning technologies use data and statistical procedures to tease out "what works" from established instructional practices and to apply proven procedures to struggling students. Teachers report spending more time on teaching subjects that are tested than ever before (CEP, 2007), and on using more assessments and implementing test preparation activities to influence student learning (Hamilton et al., 2007). Learning goals are held constant (and increasingly aligned with standards) as technologies are used to create increasingly accurate estimates of the degree to which students approached desired goals. The victory of data-driven administrative computing made the classroom into an occasion to apply and measure research-proven instructional practices.

How Technologies Will Shape the Future of Teaching and Learning

Collins and Halverson (2009) describe how learning technologies have taken different evolutionary courses in and out of schools. Some technologies thrive in schools; other technologies that seem to run counter to the aims of schooling now flourish outside of schools and animate new learning environments, such as home schooling, learning centers, video gaming, and social networking. The difference in these two kinds of technologies can be seen in the contrast of technologies for learning versus technologies for learners. Schools tend to support technologies for learning. Technologies that succeed in schools tend to define learning goals, develop structures to guide students, and provide sophisticated measures of learning outcomes. Technologies for learning minimize the active participation of the learner; in fact, such technologies are developed so that they can work for any learner, regardless of the motivation or the ability of the particular learner. Technologies for learning are essentially teaching technologies structured to reliably deliver and measure outcomes regardless of the context or the situation of the learner.

Technologies for learners, on the other hand, put the learner in control of the instructional process. Learning goals are determined by the learner, and the learner decides when goals are satisfied and when new goals are in order. This is not to say that technologies for learners are unstructured, but rather that such technologies can provide highly structured activities. The key difference is that success is measured by the degree to which the system supports and fulfills learner agency. Technologies for learners emphasize information resources, such as search engines, wikis, and blogs, that allow for information retrieval, browsing, incidental learning, and participation. Technologies for learners include programming and visualization tools, much like those described by Papert, that allow learners to construct representation of emergent hypotheses. Finally, technologies for learners are notoriously unreliable for producing anticipated results. More often, such technologies divert learning from its original goals, sometimes providing new goals, but other times simply thwarting any particular learning outcome.

We draw this contrast between technologies for learning and for learners in order to make a point about how schools have taken up some technologies and left others behind. We do not suggest that there are no technologies for learners in schools; many schools are making great strides in incorporating communication and visualization technologies into the regular school program. However, we emphasize that even when K–12 schools integrate technologies for learners, it is usually in the context of helping students achieve learning goals (e.g., standards or accountability requirements) that are not in the control of the learners. To illustrate the difference between technologies for learning and for learners, let us consider two successful online environments that have flourished in very different worlds: virtual charter schools and fantasy sports.

Virtual Charter Schools

Virtual charter schools provide an example of technologies for learning. Virtual charters are tuition-free public schools that operate under state charter school laws (Clark, 2008). Unlike other online service providers, virtual charters are "schools of record" from which a student can receive a diploma. Enrollment in virtual charter schools has grown from 31,000 in 2004 to more than 100,000 students in 18 states in 2007–08 (Center for Education Reform, 2007). The often controversial virtual charter school movement brings information technologies to bear on two trends in K–12 education: distance education and charter schools. Distance education and correspondence schooling began in the early 20th century to deliver educational content to student in remote or unconventional situations. The charter school movement of the 1990s began as a method of providing public-funded "schools of choice" that were held directly accountable for student achievement (Kolderie, 2005). Virtual charters schools, such as the Florida Virtual School (FLVS), provide state-funded access to a variety of courses for thousands of students in the state and beyond.

Virtual charter schools use many of the affordances of online learning environments. A typical virtual charter course consists of three main components: structured content and assessments, online mentoring, and a learning management system. Students enroll in a course to access structured lessons, quizzes, and projects, and to interact with teachers for help in completing the work. A learning management system that tracks logins, homework submission, communications, and logistics takes the place of the classroom. Virtual charters facilitate social learning with communication technologies, such as chat rooms and discussion boards, or contract with more sophisticated communication tools that rely on videoconferencing and presentation software. These learning technologies significantly extend the range of course delivery to students in unusual circumstances or in homeschool situations.

Seen from the perspective of technologies for learners, however, virtual charter programs have many similarities with traditional school programs. Virtual charter schools tout standards-based curricula and assessment programs that accurately measure the degree to which students learn intended content. Virtual charters also use certified teachers to provide online learning support. Students can take courses at their own pace and can choose which courses to take, but the courses themselves include traditional school staples such as algebra, life sciences, U.S. history (pre- and post-1865), and music appreciation. The courses are either developed by the school or, more frequently, contracted through a service provider such as K12.com, powerspeak.com, or FLVS. Course content includes many of the components of contemporary K–12 textbooks: multiple choice questions following text passages, matching games and flashcard activities, and short text answers. Learning technologies take advantage of virtual environments to allow for more place and pace flexibility, but courses are ultimately structured to guide learners to desired learning goals.

Fantasy Sports

Fantasy sports provide a contrasting example of technologies for learners. Halverson and Halverson (2008) argue that fantasy sports constitute a new venue for online interaction—competitive fandom—in which fans can turn interest in their teams and leagues into the experience of emulating the work of real-life managers and general managers. Lemke (2007) called this convergence of fan activity, management, and research sites an example of the kind of transmedia complex that characterizes new digital media literacy. The boundary between media consumption and media production is blurred in these transmedia spaces, where fantasy owners adapt information derived from sporting activities to manipulate the outcomes of fantasy leagues. Fantasy leagues thrive in sports ranging from American football to college and pro basketball, soccer, golf, hockey, NASCAR, and baseball. Fantasy baseball alone is played by more than 10 million people per year who spend $500 million annually on their game play (Fantasy Sports Trade Association, 2007).

Fantasy baseball leagues have grown as technologies have made it easier for team owners to track player statistics. In a typical baseball league, for example, 12 owners manage rosters of 20–25 players. Fantasy sports owners "draft" a team of players in a given sport and follow the performance of this collection of players against the teams of other owners in their league. Team owners can typically trade, acquire free agents, use disabled lists, and manage rosters and salaries much like their real league counterparts. Game play allows players to test increasingly sophisticated hypotheses of game play as they become more experienced players (Bereiter & Scardamalia, 1993; Gee, 2003). Each game the player plays contribute to the team statistics—each run scored, base stolen, strikeout, or run allowed—establishes the standing of the fantasy team owner. Fantasy team owners win when the teams they draft are more successful than other teams in their fantasy league. Web sites such as yahoo.com, espn.com, or csb.sportsline.com provide the league management systems through which team owners manipulate rosters. Within the league sites, owners can create user profiles, research players for trades or roster moves, and link to social networking fan sites.

Activities such as fantasy sports provide a good example of technologies for learners. Although it might be argued that fantasy sports is an entertainment activity that has nothing to do with learning, Johnson (2005) and Jenkins et al. (2007) suggest that such online participatory communities will continue to blur the lines between learning and entertainment. Fantasy sports players typically begin as sports fans and use the resources available in fantasy leagues to deepen their knowledge of player performance. Technology resources are organized to support players' agency. Although the system has clear goals (e.g., winning), players can participate as much (or as little) in the preparation and research phases of league play as they desire. Players can simply enjoy the camaraderie of online social interaction or can become fiercely competitive to gain an edge on other players. Savvy players take advantage of the fantasy transmedia complex to use other fantasy sites and podcasts and, most important, to watch games to get tips on game play. Learning technologies take advantage of virtual environments to provide access to resources that learners can choose to exploit.

Learning versus Winning

Virtual charter schools and fantasy sports illustrate technologies that flourish in education and those that thrive outside of education. Both environments use information and communication technologies to structure the goals and the experience of learners. Both environments leverage social interaction (with teachers and with other players) to resolve learning difficulties and motivate participation in the system. A key difference, however, lies in the contrast of learning versus winning. Virtual charter schools aim to create the conditions for all students to learn; fantasy sports create an environment in which some players can win.

Part of this contrast is reflected in the issue of who controls the learning experience. Although students elect to enroll and take classes in virtual charter schools, once enrolled, the school uses technology to control the learning experience in order to provide predictable learning outcomes. This emphasis on controlling the learning experience creates a coupling between the system goals (student acquisition of standardized content) and the learner goals (course completion). The school must create structures that motivate students to use provided resources to achieve system goals. Incidental learning may occur in the virtual charter environment, but learning in terms of stated outcomes is what gets rewarded. Fantasy sports, on the other hand, are organized as learner-controlled activities. Fantasy sites provide resources to attract players to the site, but the goals of participation in a league are left to the players. As the players determine goals for why they play, the technological system is designed to support a variety of player goals. With learner goals come learner responsibilities. Fantasy games have conditions for participation and for success, but the burden is on players to assemble the necessary knowledge and resources to meet the system goals (winning). Unlike virtual charters, fantasy sports support learning as an incidental outcome of play, not as an end in itself. The concept of learning outcomes, so important for charter schools, is a happy outcome of some fantasy sports experiences.

The contrast between learning and winning highlights another difference between controlled learning and learner control. Virtual charter curricula are organized to ensure that any student, given the required skill and commitment, can successfully acquire course content. Virtual charters organize technologies to support democratic learning environments that guarantee the equitable opportunity for students to achieve learning outcomes. By contrast, the fantasy sports focus on winning creates a meritocratic system in which many players necessarily fail and few win. Fantasy sports are meritocratic learning environments that encourage players to develop idiosyncratic strategies in order to win. The game provides clear, direct assessment of game-play strategy (winning and losing) and provides ready access to the alternative strategies (used by other players) for players to refine their own strategies. The democratic versus meritocratic contrast of school and games may be deceptive, however, when considering issues of student/player motivation. Maintaining student engagement in virtual school courses requires the use of incentives from outside the learning system, such as grades, credits, or diplomas. Games have internal structures that motivate players, even when they lose, to continue playing (Gee, 2003). Although democratic structures may favor wider initial access to participation, meritocratic structures may better motivate continued engagement with the system.

Conclusion

In this brief recounting of the recent history of technology development, we arrive at several concluding thoughts. First, it is impossible to foresee the effects of new technologies on complex, well-established institutions. Gardner (1985) had the advantage of hindsight to trace how the seminal insights of early cognitive researchers blossomed into new branches of research. Papert's vision, on the other hand, extended his insights into the future to predict how computing might change teaching and learning. As we have seen, schools seemed to pick up on affordances that reinforced institutionalized priorities. Rather than opening up new opportunities to reframe how teachers teach and students learn, it seemed as though instructionalism bent technologies to extend existing pedagogical, curriculum delivery, and assessment practices. Accountability policies created a need for information technologies to regulate how schools collect and act upon assessment information. Thus, although technology enthusiasts expected a revolution in technologies for school learners, what schools experienced was a revolution in technologies for measuring and guiding learning. The learner revolution took place outside the schools.

Teachers are at the center of instructional practices in schools. Powerful information tools could help but have significant effects on teaching practices. Some of these effects followed from the imposition of new technologies measuring and assessing learning. However, new information technologies continue to cause unanticipated effects on classroom teaching practices. The technologies and practices of accountability, for example, have transformed early elementary reading teaching. Many elementary schools have developed just the kinds of learning organizations anticipated by Senge (1990). Here teachers work in collaborative teams, using data to measure the results of their practice and redesign how they do their work. Educational specialists who were previously relegated to separate resource rooms have reframed their work as coaches, analysts, and service providers in the context of the regular classroom. These teachers are engaged in practices that allow them to "continuously see the whole together" (Senge, 1990). Interestingly, while many teachers who engage in such collaborative work may say that they do not use technologies in their everyday teaching, we can begin to see how changes in their practice can result from the ubiquity of information technologies in schools. These practices are not yet universal and still exist alongside traditional classrooms. Still, the existence of these nascent learning organizations testify to how information technologies, sparked by accountability policies, can reshape the tradition-bound practices of K–12 classrooms.

Finally, we must view the institutional pull toward co-opting the potential of technologies in the larger context of education and society. Collins and Halverson (2009) describe how education became synonymous with schooling in the early 20th century. The rise of information technologies has called the identification of schooling and learning into question. While schools adapt technologies to proven approaches to teaching and learning, technologies in entertainment, communication, and business have sprouted into the seeds of a new education system on the margins of schooling. Homeschooling, blogging, participatory media, video gaming, learning centers, and social network sites show how interest-based learning communities can flourish outside the boundaries of schooling. Schools may well continue to be places that seek to provide safe, equitable, and reliable opportunities to learn for the majority of K–12 learners. Communication technologies will also continue to spark new learning opportunities—some of which will align with school priorities, and some of which will flourish outside of school. Instead of opposing in-school and out-of-school learning, the advent of new learning technologies describes a pluralistic world in which out-of-school learning can complement in-school education.

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