TECHNOLOGIES FOR TEACHING SCIENCE AND MATHEMATICS IN THE K-12 SCHOOLS: REVIEWS, OBSERVATIONS AND DIRECTIONS FOR PRACTICE IN THE SOUTHERN UNITED STATES

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ABSTRACT

This paper introduces a set of papers focusing on the issues and practices in using technologies for teaching and learning science and mathematics in the K-12 schools in the Southern United States where the digital divide between technology rich schools and technology poor schools is growing wider despite attempts to provide funds and standards to bring the schools to national standards. In particular, the paper discusses the current political and theoretical stances that entangle the schools, methodological issues in the collection of data on technology integration in science and mathematics classrooms, a framework for technology integration into the various levels of education, and the governance and funding structures of the schools. The individual presentations focus on the following levels: K-3rd, 2nd-5th, 5th – 8th, and 9th-12th. Teachers and students at every grade level are gradually entering more and more technological environments as our societies have jumped into highly technological workplaces. These environments produce a variety of concerns for teachers related to the appropriateness of designing instruction that uses communications technology, multimedia and various hands-on technologies. In the United States, learned societies, professional organizations and accrediting agencies include a variety of technological skills in their standards and benchmarks, although many practicing teachers have had no training in using current multimedia technologies.

KEYWORDS

Technology integration, science teaching, mathematics teaching, access to technology, schooling systems in the U.S.A., methodologies

INTRODUCTION AND POST-MODERN APOLOGY

In our post-modern world, the schools must serve many masters and theoreticians as they develop learners' abilities in science and mathematics. These masters include the political, the civic, the social and the economic engines that drive transnational economies in a technological age. Theoreticians provide us with lenses into the meanings we construct in our interpretations of complex sociopolitical institutions like the school. In this brief introduction, I mention only a few of the issues facing the schools in the southern United States of America as they incorporate current science and mathematics standards in their curriculums. A discussion of the current political and theoretical stances which entangle the schools, methodological issues in the collection of data on technology integration in science and mathematics classrooms, a framework for technology integration into the various levels of education, and the governance and funding structures of the schools are included.

The schools of our republic (the United States of America) are governed by a tangle of regulatory agencies, entities and individuals, including the federal bureaucracy (under the control of executive departments like the U.S. Department of Education), the judicial fiats of the Supreme Court, and the legislative milieu of Congress with its changing political control structures; the sovereign powers of the state (e.g., Louisiana with its contradictory controls of Code Napoleon and common law) that mirror the structures of the federal government with policies purveyed by legislatures and appointed state school boards; local governance from counties, cities and elected school boards; administrative structures of the school systems with superintendents, teams of curriculum specialists and bureaucratic functionaries like the overseers of the payroll computers and data collectors; professional accrediting agencies like the Southern Association of Colleges and Schools and the National Council for the Accreditation of Teacher Education; learned societies purveying standards for teacher, school and student performance (i.e., the International Society for Technology in Education (2002), the National Council of Teacher of Mathematics (NCTM, n.d.) and a host of science organizations (e.g., National Science Education Standards; n.d.; Science for All Americans, n. d.)); text book publishers; religious organizations; non-governmental funding agencies (e.g., the Bill and Melinda Gates Foundation), and teachers, parents and students. Using a variety of industrial, behaviorist accountability standards, public schools are now ranked and graded base primarily on data from standardized tests with minimal regard for the nature and cultures of the learners who attend as if they were to become interchangeable performers in the postindustrial economy.

The theoretical lenses on the schools are equally complex. Behaviorism (Bandura, 1969), social cognitive learning theory (Bandura, 1986), social interactionism (Vygotsky, 1978, 1986), social/cultural reproduction (Bourdieu & Passeron, 1977), pragmatisim (Dewey, 1909/1975,1916/1966, 1927, 1934, 1938), the various flavors of constructivism from radical to social to methodological (Bereiter, 1994; Phillips, 1995; Steffe & Kieren, 1994; von Glaserfeld, 1995), feminisms (Belenky, Clinchy, Goldberger, & Tarule, 1986; Gurian, 2001), liberation theology (Freire, 1985, 1993), postcolonialism and multicultural/race theories (Banks, & McGee-Banks, 2001; Gibbs, & Huang, 1997; Ladson-Billings, 1997), multiple intelligence theory (Gardner, 1993), complexity theory (Briggs, & Peat, 1990; Gleick, 1988), and critical theory (Apple, 1995; Giroux, Lankshear, McLaren, & Peters, 1996) play their parts as we tell the stories of teachers' work in classrooms where the instructional content is mathematics and the sciences and where technologies provide some students with almost unlimited access to the virtual multimedia world while others rarely venture beyond traditional textual representations of classroom realities (LeBaron, & Collier, 2001; Means, Penuel, & Padilla, 2001; Schofield, & Davidson, 2002; Zucker, & Kozma, 2002). Experiences of mathematical and scientific thought (the experiential, the multimedia and the textual) can be supplemented, enhanced and interpersonally corroborated with teaching environments rich in hands-on, manipulative, socially communicated experiences in laboratories where teachers guide inquiry, problem solving, hypothesis testing and data-driven interpretations of appropriate content for the learners situated in their schools laboratories and field-based actions in diverse local communities where communication technologies can throw local activities into international communicative environments of the web.

These multifaceted influences on the modern educational system lead to four guiding questions for the papers in this symposium: What aspects of multimedia and communications technologies are appropriate for teaching science and mathematics concepts and practices at different developmental levels? What technologies are teachers using to teach science and mathematics at different developmental levels in the United States? What inequities or divides still exist in technological access for science and mathematics teachers and their students at different developmental levels, especially in schools dealing with diverse students and children of poverty? In the current standards and achievement test driven educational situation, how are individual schools and teachers of science and mathematics integrating technology into their instructional practices? I will now provide some notes on the methodologies used in the papers which follow, a brief discussion of a technological framework for communicating and teaching science and mathematics in the K-12 schools, and then set the stage for the four papers in the symposium with which we hope to open the debates about how teachers can improve teaching and learning with technology and developmentally appropriate practices in their local schools.

SOME NOTES ON METHODOLOGY AND THE TECHNOLOGY FRAMEWORK

The authors of the papers for this symposium have long standing interests in technology integration into instruction. Most of them have participated in the New Orleans Consortium for Technology Integration and Implementation in Teacher Education (NOCTIITE, Speaker, 2002) and have been active in studying and observing teaching with technology in the schools. As part of this process we have collected various streams of evaluation data related to NOCTIITE and analyzed it for technology integration in the teaching of sciences and mathematics. In general this data is qualitative in nature, leading to narrative analysis (Bruner, 1990, 1996; Clandinin, & Connelley, 1999), case study methods (Merriam, 1999), and portraiture (Lawrence-Lightfoot, & Davis, 2001) within a post-modern, interpretivist stance (Foucault, 1972). Each observer acts as a tool recording and interpreting the situated events in classroom contexts. The goal of the evaluation system for NOCTIITE was to provide both formative and summative information about the ongoing and cumulative effect of the project. Thus, the system was designed to summarize, analyze, and interpret data collected systematically within and across the three years of the project itself by various stakeholders and the follow-up years beyond the scope of the project.

NOC-TIITE had as its goal to make ubiquitous the use of various modes of technology in teaching in two separate, but interrelated, spheres – university teacher education and K-12 classrooms – with the added expectation that a mutually beneficial transactive relationship that would occur between these spheres as a result. A guiding belief of the project was that students educated in Teaching with Technology (TWT) will, themselves, make use of many modes of technology in their K-12 field experiences and will, in turn, stimulate university faculty to increase the sophistication of the technology presented in subsequent methods classes; concurrently, university faculty in the TWT project will become increasingly able and willing to embed technology in methods classes and will, in turn, stimulate student teachers to higher levels of sophistication in using technology; further, K-12 children will benefit from interdisciplinary instruction that is project-based and technology rich. The data streams are complex and nuanced and cannot be adequately evaluated by a focus on any single participant group. Furthermore, two recent dissertations have looked at aspects of TWT among faculty in higher education (Wang, 2002) and high school biology teaching (Malone, 2002).

In examination of the situations of TWT, two kinds of data were collected:

1. *Portrayal Data*. These data are concerned with the landscape and focus on documentation of the classroom and school profiles from the beginning of the study and throughout. What do classrooms and schools look like? What is going on in them? What is taught and learned? How is it taught? Who are the stakeholders? What is the profile of each stakeholder group? What are the expectations of each group from the others? What is the effect of TWT on each stakeholder group over time? Field interviews, questionnaires, observations, videotaped lessons and events, and other documentary information (e.g., numbers of computers in classrooms, time spent engaged with technology, etc.) will be used as evidence for the portrayal data. Data collection occurred throughout the course of the project, for the purpose of documenting change over time. Portrayal data included university faculty, their students/student teachers, K-12 teachers and students in whose classrooms the students/student teachers work, and the university and K-12 classes and classrooms themselves.
2. *Perception and Satisfaction Data*. These data are concerned with value added to university and K-12 instruction that already exists; in other words, what has the TWT project experience added to the quality of teaching and learning in university methods and K-12 classrooms? What do graduates of the TWT teacher education programs offer to K-12 schools that graduates of other programs do not? What do university faculty participants in TWT offer to teacher education programs that other faculty do not? How sustainable are the benefits of TWT? How does the TWT project experience affect the conversation between stakeholder groups? Journal entries, e-mail and on-line fora conversations were used in addition to field interview, questionnaire, and observation as evidence for the perception and satisfaction data. Data collection occurred at significant points in the project events – end-of-semester, end-of-institute, end-of-year, end-of-project – to allow sufficient time for value added to be perceived.

For the purposes of these symposium papers, these rich qualitative streams of data collected for the project and by the authors of various papers were mined for contexts and narratives of TWT which illustrate the uses of technology in the teaching of mathematics and science at various levels.

Out of the streams of data on various levels a framework of technology use gradually emerged. This framework is represented in the table below. This framework emerged from our discussions of the various data streams and cross-referencing with technology standards from International Society for Technology in Education (ISTE, 2002) and other organizations.

Table 1. Framework of Technology Use in K-12 Classrooms

Levels **U.S. Grades** **Descriptor**	**Early Elementary** **K-3**	**Upper Elementary** **3-6**	**Middle School** **6-8**	**High School** **9-12**
Equipment	Computers, projection device, printer, floppy drives, CD-drives, web connections, scanner; Issues about the number of computers in the classroom	Computers, projection device, printer, scanner, laptops, probes, floppy drives, CD-drives, web connection; Issues about the number of computers in the classroom	Computers, projection device, printer, scanner, laptops, probes, floppy drives, CD-drives, web connection, CD burners; Issues about the number of computers in the classroom	Computers, laptops, projection device, printer, scanner, laptops, probes, floppy drives, CD-drives, web connection, CD & DVD burners; Issues about the number of computers in the classroom
Software	KidPix, Hyperstudio, Word, Simple graphically-oriented simulation software	PowerPoint, Word, Excel, image editing, initial web design, complex graphically-oriented simulation software	PowerPoint, Word, Excel, image editing, video editing, full web design packages, HTML	PowerPoint, Word, Excel, image editing, video editing, programming languages, full web design packages, systems, scripts, Java
Ease of Software Use	Very easy, intuitive software	Basic packages with intuitive interfaces, Initial web design (pages and links), placing images	Sophisticated use of Office, full web design, image editing, and browsers	Personal and project webpages incorporating images, forms, animations, digital video, cookies
Input System Use	Initial activities with easy beginning software for typing, mouse control and various touch pads (To be replaced with word recognition systems in the future)	Advanced activities with the full range of software for teaching typing and other input devices	Proficient with most input devices	Proficient with all input devices
Internet Use	Directed by the teacher	Webquests, Simple searching, using selected webpages	Full search and research capabilities, Understanding of web hosting	Security of web sites and initial business concepts

Level of Learner Activity with Technology	Slight, mostly viewing selected activities and participating with selected multimedia software	Moderate, initial choices of software, viewing and constructing multimedia for small presentations	Consistent, wide range of choices and occasional construction of multimedia for presentations	Full, extensive range of choices and regular construction of multimedia for presentations
Multimedia	Digital still camera for collecting images, CD's, floppies	Digital Video for collecting images with minimal editing, CD's, floppies, DVD's, DV cassettes	Digital Video with editing and webpage insertion, CD's, floppies, DVD's, DV cassettes	Digital Video with software enhancements like Flash, sound dubbing, CD's, floppies, DVD's, DV cassettes
WebSite Evaluation	Topic appropriate for learners	Websites for use with peers about particular topics	Accuracy, currency and appropriateness of the websites for peers	Appropriateness of websites and links for different learner groups
E-mail for Students	Teacher controlled and filtered	Mentored keypals and e-mail through teacher	Forums, full use of e-mail, chat	Personal webpages with chat, forums, forms and e-mail facilities, wireless connectivity control
Communication with Parents and the School Community	Webpage about school and classroom, activities for parenting and support of learning, and special activities; occasional e-mail contact	Webpage about school and classroom, homework, and special activities; newsletter from the class by members of the class; regular e-mail contact	Webpage about school and classroom, homework, and special activities, segments maintained by the children in the class; moderated class forums and groups; e-mail contact for special purposes	Webpage about school and classroom, homework, and special activities, segments maintained by the children in the class; moderated class forums and groups; e-mail contact for special purposes
Trouble Shooting	Basic connections to power & internet, basic parts	Connecting drives and setting up internet connections	Control panels and preferences	System trouble shooting and compatibility issues, wireless communication control
Ethical and Legal Issues	Sharing, Discussions of Appropriateness for the classroom	Noting sources from the web, Discussions of Appropriateness for the classroom	Full attribution and knowledge of fair use, Discussions of Appropriateness for the classroom	Security and appropriateness of pages for different groups

The framework, developed under the auspices of the New Orleans Consortium for Technology Integration and Implementation in Teacher Education, examines equipment, software, ease of software use, keyboard use, internet use, level of learner activity with technology, multimedia, web site evaluation, e-mail for students, communication with parents and the school community, trouble shooting and ethical and legal issues at each age/developmental level. It will receive further explication in each of the papers of the symposium.

SETTING THE STAGE FOR THE DESCRIPTIVE PAPERS: CONTEXTS AND DIRECTIONS

The specific schooling contexts in Louisiana, where our data were collected, provide an extreme example of the educational division present in the Southern United States. Louisiana has a tripartite educational structure consisting of the public school systems, the Catholic systems, and individual private schools. The Louisiana State Department of Education enforces different rules for each of these categories of schools and for the small fourth educational division, the charter schools. Each public school system is governed by an elected board of local members from the citizens of the district, which is contiguous with the governmental unit within the state (this is called a parish in Louisiana but is called a county in all other states). The chief executive officer of each public school system is a superintendent, appointed by the board and usually someone with considerable educational and management experience, although recently retired military officers have taken the post. The public school systems range from sprawling urban systems with over a hundred schools to small rural ones with only a few. In Louisiana, only about 40% of students attend the public schools. The Catholic systems have a board and superintendent but the membership of the board is selected in various ways according to the policies of the particular diocese. The private schools have a variety of organizational and governance structures and are only loosely affiliated through professional organizations. The final category of schools, charter schools, is made of public schools receiving a special charter and governed minimally by the public school board and the State Department of Education. Most of these schools are also supported by parents' organizations that contribute advice, funds and projects to support the learners and the schools

All of the schools receive some public funds for books, record keeping and equipment, but their funding structures and accountability measures are very different. Public schools receive most of their funding from the state; however, for districts with populations of students from high poverty areas, substantial federal funds are supplied through the U.S. Department of Education under programs such as Title I. Individual public schools have been funded in various ways through grants and parents' organizations. Teachers, administrators, parents and alumni have written grants to supply technology to schools from various state, federal and non-governmental sources. In some cases, parents' organizations have build entire computer laboratories and in one case, school buildings have been funded by this means. The Catholic school systems receive support from the state, from the church and from tuition. Tuition for most of these schools is moderate, ranging from about $1200 to $4000 per year; however, special programs for learners with difficulties and special needs can cost up to $8000 per year. The private schools tend to be expensive and most of their funding comes from tuition and endowments from alumni. The annual cost for private schools can be as high as $12,000 per student. Because of this higher level of funding, private schools tend to be well staffed and technology rich, displaying a dramatic Matthew Effect (the rich get richer while the poor get poorer).

Current reform efforts in education have been directed primarily towards the public school systems. Politicians have promulgated the idea that these schools are failures because test scores show that learners from poverty do not perform as well, on average, as learners from middle class or wealthy backgrounds. This performance problem seems inherent and widely recognized internationally by such scholars as Bourdieu and Passeron (1977), but, in the U.S., it has become a marker of systemic failure, despite the complex needs of educating a very diverse, multicultural population. This problem has generated three major trends in reform: 1) standards-based science and mathematics teaching revisions promulgated by professional organizations of science and mathematics teachers and accrediting agencies for higher education units preparing teachers; 2) accountability systems with corrective actions for school not meeting new test standards; and 3) major redesign of teacher preparation mandated by state legislatures. The effects of these reform efforts have included: 1) an emphasis on inquiry, problem-based learning, technology integration and collaboration in science and mathematics learning and teaching without funding for supplies, equipment and retraining of practicing teachers while general teaching has increased emphasis on test taking practices; 2) punishment and disruption of school cultures where students do not show annual growth as measures by standardized tests; and 3) costly, time-consuming and technologically demanding systems to control the preparation of teachers, including mandated follow-up and support of new teachers by their university programs, a plethora of new tracks for teacher preparation, and on-line electronic portfolio systems for constant progress evaluation which do not yet function (all without funding or staff increases).

CONCLUSIONS

The descriptive papers which follow (Buxton, Hall, & Speaker, 2003; Germain-McCarthy, Haggerty, Buxton, & Speaker, 2003; Kieff, & Speaker, 2003; Willis, Longstreet, & Speaker, 2003) and their presentations are designed to bring readers up to date descriptions on the issues and practices in using technologies for teaching and learning science and mathematics in the K-12 schools in the Southern United States where the digital divide between technology rich schools and technology poor schools is growing wider despite attempts to provide funds and standards to bring the schools to national standards. The individual papers focus on the following levels: K-3rd (Kieff, & Speaker, 2003), 2nd-5th (Buxton, Hall, & Speaker, 2003), 5th – 8th (Willis, Longstreet, & Speaker, 2003), and 9th-12th (Germain-McCarthy, Haggerty, Buxton, & Speaker, 2003). Teachers and students at every grade level are gradually entering more and more technological environments for their teaching of mathematics and sciences as our societies have jumped into highly technological workplaces. These environments produce a variety of concerns for teachers related to the appropriateness of designing instruction that uses communications technology, multimedia and various hands-on technologies. In the United States, learned societies, professional organizations and accrediting agencies include a variety of technological skills in their standards and benchmarks, although many teachers have had no training in using current multimedia technologies. Each paper addresses the issues from the current theoretical social constructivist viewpoint, providing portraits of practices that incorporate technology in at least two schools, one technology rich and the other technology poor. Despite efforts at reform on all levels of education in the United States, Matthew effects (the rich get richer) are rampant in our observational data, even as individual teachers make use of available technology in schools that are technologically poor.

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