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Editorial: Developing Technology Policies for Effective Classroom Practice

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Information technology has changed both business and society in recent years. Just as the advent of electronic media shaped society at the beginning of the 20th century, the capabilities of the Internet are changing our world in the 21st century. Substantial efforts have been made to ensure that schools are woven into the infrastructure of the web. Every school and virtually every classroom in the United States have been connected to the Internet. Other efforts such as the One Laptop Per Child initiative (see http://laptop.org) have been undertaken to extend the mesh of connections worldwide. Despite these investments, schools are not yet demonstrably more effective.

The most recent large-scale study of technology in schools, sponsored by the U.S. Department of Education did not yield a statistically significant difference for classes using selected reading and mathematics technology applications. A guest editorial in the previous issue discusses some of the implications of the findings (Fitzer et al., 2007). The authors noted that the study provides "a valuable, un-retouched snapshot of how instructional technology is used in our schools" even though it offers "little guidance for researchers, educators, developers, and policymakers who wish to develop better ways to take advantage of educational software" (para. 22).

The challenge of using technology effectively in schools is one that has been described as a "wicked" problem (Rittel & Webber, 1973) with incomplete, contradictory, and changing requirements characterized by complex interdependencies among a large number of contextually bound variables. The wicked problems of technology integration require us to develop innovative and creative ways of confronting this complexity. Research indicates that such innovation occurs best at the intersection of disciplines and that "the more diverse the problem-solving population, the more likely a problem is to be solved" (Lakhani, 2007).

Our goal in this editorial is to set the stage for such interdisciplinary collaborations to tackle the wicked problem of technology integration in teaching. The *CITE Journal* is published by a coalition of teacher educator associations [1], the National Technology Leadership Coalition (NTLC). Each of the participating associations is individually committed to advancing effective use of technology in schools and, thus, NTLC provides a venue for joining forces across diverse disciplines. An annual leadership retreat, the National Technology Leadership Summit (NTLS), convenes this diverse problem-solving population to consider the critical issues facing the research and scholarly community around technology integration.

The next meeting of the NTLS (the ninth, hence NTLS IX) is scheduled for this fall. In this editorial we describe key themes to be discussed.

Thinking About TPCK

A critical aspect of thinking about technology integration is the diversity of disciplines. Shulman observed that crucial aspects of pedagogical practice are uniquely connected to specific content areas, coining the term "pedagogical content knowledge" (Shulman, 1986). Extension of the concept to "technological pedagogical content knowledge" (TPCK) brings much-needed recognition of the central role of content and pedagogy in uses of educational technology – a role often missing in discussions until recently (Mishra & Koehler, 2006).

As Mishra and Koehler argued, realizing the potential of the technology requires skills and knowledge not just of technology, pedagogy, and content in isolation but rather of all three taken together. Teaching successfully with technology requires continually creating, maintaining, and re-establishing a dynamic equilibrium among all three components.

Teachers constantly negotiate a balance between technology, pedagogy, and content in ways appropriate to the specific parameters of an ever-changing educational context. Teachers construct curricula through an organic process of iterative design and refinement, negotiating among existing constraints to create contingent conditions for learning. In particular the TPCK framework emphasizes the critical role of the teacher as curriculum designer — the awareness that teachers are active participants in any implementation or instructional reform we seek to achieve and, thus, require a certain degree of autonomy and power in making pedagogical decisions.

This emphasis on the interaction among the three components implies that content-neutral approaches toward technology integration will not succeed. Research on learning shows that effective instruction must teach the structure of a discipline (Bransford, Brown, & Cocking, 1999). This is particularly critical in today's increasingly globalized world where deep understanding of subject matter (particularly in the disciplines of science, mathematics, technology, and engineering) needs to be developed. Generic uses of technology that do not emphasize the deep ideas of a discipline do not lead to deep conceptual understandings.

An example of this de-emphasis on content can be seen in the recent study sponsored by the Department of Education (Dynarski et al., 2007). A majority of applications evaluated in this study were tutorial programs — applications that employ technology as a delivery system. This type of use may not take full advantage of technology to address specific aspects of the nature of the content to be covered and the role of the teacher in representing it in pedagogically appropriate ways. In other words, these applications represent a specific approach to use of technology that embeds a transmission model of learning.

This approach is in direct contrast to the ideas at the heart of the TPCK framework and the beliefs undergirding the establishment of NTLC — that is, that technology should be introduced in the context of content instruction and that teachers should take advantage of the unique features of technology to teach content in ways they otherwise could not (Garofalo et al., 2000). If the pedagogical content knowledge required for each discipline differs, it follows that the ways in which technology might best be used for each discipline may also differ.

The threefold frame for thinking about technology integration (T, P, & C) can be developed in multiple ways (Figure 1). For instance, one could focus on Pedagogy, and see how it interacts with Technology and Content. Alternatively, one could focus on one content area, and see how Pedagogy and Technology can be best utilized to develop student understanding of core content ideas.

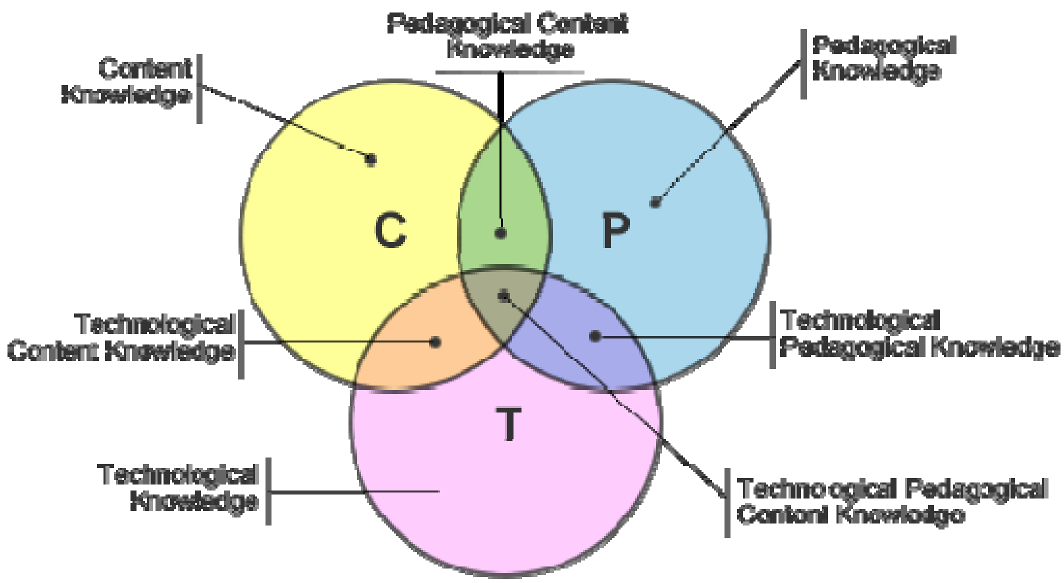

Figure 1. *The TPCK framework.*

In this initial exploration we examine the third possibility of considering the affordances (and constraints) imposed by one particular technology and its interaction with content areas and pedagogical goals. We do this with a sensitivity to the limitations inherent in such an approach, but also with an understanding that identifying potentially promising models and empirically assessing their efficacy in classroom use pose significant challenges.

Teachers need to know which technologies can be combined with appropriate concepts in specific content areas. Our intention is to develop examples within each of the content areas, focusing first on a single pervasive technological application. The different uses of technology to address different pedagogical goals within each content area may help clarify the usefulness of TPCK as an organizational framework.

In the forthcoming NTLS meeting, we have chosen to focus on digital video as a context for further fleshing out the TPCK organizational framework. This will constitute the second major strand of the meeting. Digital video is permeating every facet of the Web, from user-contributed videos on YouTube (www.youtube.com) to the short video clips now frequently accompanying stories on the *New York Times* and *Washington Post* Web sites. Hence, it seems an appropriate focus for our work in developing illustrations of TPCK and for consideration at NTLS IX.

Implications of TPCK for Digital Video

There are today a number of educational video sites modeled on commercial or public Web 2.0 technologies such as YouTube. These sites often archive (with easy search capabilities) video clips of educators talking – essentially employing technology as a conduit for the *transmission* of information. There is undeniable value in capturing and sharing the world's most creative teachers' discussions of their favorite subjects. However, we argue that limiting the use of digital video to the mere transmission of classroom lectures does not take full advantage of the capabilities of the medium.

In contrast, we believe that digital video technologies offer unique opportunities (through interactivity and user-generated content) to rethink the instructional paradigm particularly to match the needs of the subject to be taught. The technology now makes it possible to capture computer displays to create screencasts, combine images with student narration for digital storytelling, and construct digital animations such as Flash movies, among other possibilities. As a result of emergent technological advances and concomitant expansion of the affordances of the medium, the definition of digital video and digital movies is broader than in the past. As we shall see, the best uses of digital video can vary dramatically from one content area to another.

Digital Video in Science

Digital video can be used in many different ways for science education. One particularly important pedagogical role digital video can play is in addressing common student misconceptions. Students at all levels have misconceptions about physical phenomena and often have difficulties conceptualizing scientific events. These conceptions occur due to a variety of reasons, and digital video can be an important tool in an educator's toolkit to help students go beyond immediate perceptions toward more nuanced and complex (and scientifically accurate) understandings.

For example, consider the classic science demonstration where an egg is pushed into a milk bottle by the burning of a paper inside the bottle (Figure 2). There is a common misconception that the egg is forced into the bottle due to a drop in pressure caused by the depletion of oxygen as the paper burns.

Figure 2. *Egg-in-the-Bottle demonstration.*

The actual story is more complex. The heat of the flame causes the air inside the bottle to expand and, thus, initially increases the air pressure inside the bottle. This increased pressure forces air out of the bottle, past the egg (which acts as a one-way valve). When the remaining air inside the bottle subsequently cools, a drop in the air pressure occurs, causing the egg to be pushed into the bottle by the external air pressure.

Adding a pressure sensor to the demonstration can allow students to replay a video of the experiment with a graph of the internal pressure superimposed beside the video. By providing synchronized multiple representations of the event, students can visualize the meaning of the graph and connect the graph to pertinent features of the phenomenon (Figure 3).

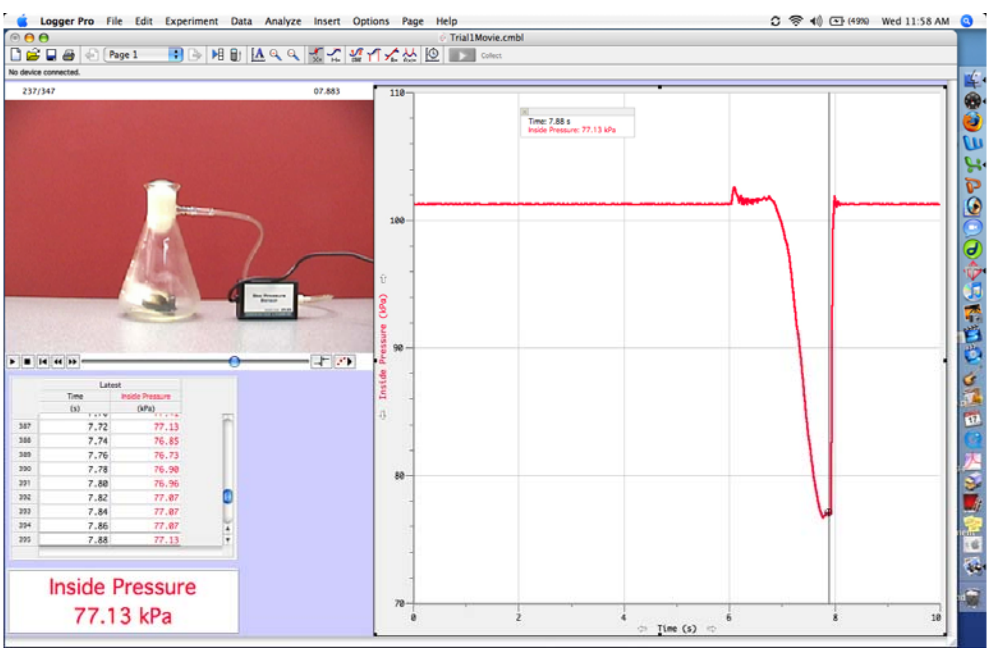

Figure 3. *Computer screen synchronizing video, data, and graph.*

Thus far only limited research has been conducted on use of synchronized video combined with graphical representations of data in the science classroom. Controlled, replicable research documenting quantifiable outcomes in classroom use will be needed to determine the potential benefits.

Digital Video in Social Studies

In contrast, ready access to primary source documents offers social studies teachers the possibility of different kinds of instructional approaches. Digital history centers and institutions such as the Smithsonian and the Library of Congress are increasingly making digital copies of historical documents such as photographs, artwork, and maps available online. These digital resources afford students the opportunity to create digital documentaries – short digital movies that contain a montage of images, text, or video accompanied by a narration done in the student’s voice. Educators believe that students who effectively use primary source documents can develop enhanced historical thinking skills.

Development of digital documentaries incorporating primary source documents has been used to good effect in isolated classrooms. However, widespread classroom use faces significant barriers. Digital movies can be resource intensive and time consuming to develop. The digital movies we envision do not embody the "turn the projector on and let the film teach" methods of 40 years ago. Instead, they provide a platform from which students can dive into inquiry — to interact and engage with content. Adequate teacher preparation and support are crucial to effective use.

Digital Video in Language Arts

Evidence exists that struggling readers sometimes have difficulty forming accurate images associated with the words that they are reading. The ability to combine images with words to create digital movies offers an avenue for reinforcing visual imagery — contextualizing the text in ways not previously possible. When the words are narrated in the student’s own voice, the process may also offer opportunities for auditory reinforcement.

Interactive Digital Video in Mathematics

Digital movies are used in a very different way in mathematics instruction. School math frequently begins with an equation that is used to generate a series of numbers. These numeric values can be plotted to generate a graphical representation (Figure 4).

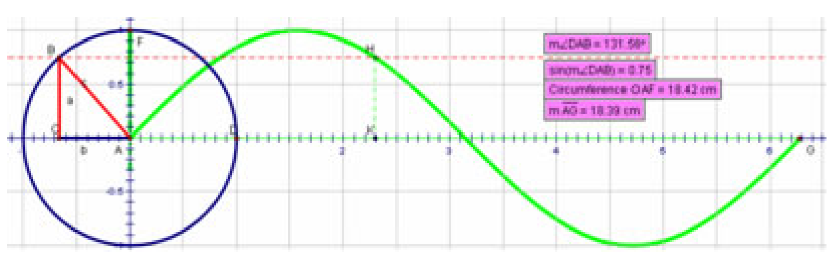

Figure 4. *Graphical representation of a sine function in Geometer’s Sketchpad.*

For example, the plot of a sine function generates a series of numbers between +1 and -1. Students typically experience difficulty in understanding the relationship between a triangle and the characteristic shape of a sine wave – one has three sharp corners while the other has rounded peaks and valleys. This relationship is difficult to see in a static image in a textbook. However, when a tool such as the Geometer's Sketchpad is used to create a digital animation over time, the relationship is more easily understood. The potential is further enhanced when the possibility of interactivity is considered — that is, students manipulating the variables and seeing changes to the animation or video in real-time.

Constructing a TPCK Matrix for Digital Video

These examples in science, social studies, language arts, and mathematics illustrate the substantial differences in affordances and uses of digital movies and animations in different disciplines. Table 1 suggests ways in which one technology, digital video, can be used to address different pedagogical goals in different content areas.

Table 1
An Illustration of Linking a Technology (Digital Video) With Pedagogical Goals in Different Content Areas

Discipline	**Content**	**Technology**	**Pedagogical Goals**
Science	Physics	Digital Video	Rectifying Naïve Conceptions
Social Studies	History	Digital Video	Supporting Historical Inquiry
Language Arts	Reading	Digital Video	Reinforcing Visual Imagery
Mathematics	Trigonometry	Digital Video	Connecting Representations

Even this overview does not convey the full range of complexity in our thinking about integrating technology in teaching. For instance, each row of the table represents one discipline — possibly implying, for instance, that the only goal in mathematics education is that of developing connecting representations. Nothing could be further from the truth. It is important for us to understand that there can be (and are) varied pedagogical goals even within specific disciplines and content areas.

For instance, in mathematics the pedagogical goals (and concomitant pedagogical strategies) for learning the multiplication tables are very different from those involved in learning algebra (such as the idea that "*x*" can stand for the unknown) or in understanding the trigonometric concepts of a sine function. The multiplication tables may be best learned through drill and practice or tutorials, algebraic variables through analogy, and trigonometry through simulations.

The actual solution space is far richer, with multiple technological approaches, but these three examples suggest the myriad possibilities. Our point here is that the full range of possibilities should be employed, matching the tool to the pedagogical goal and need, including tutorials (the type of software represented in majority of applications evaluated in the Dynarski et al. study), as well as other strategies and approaches made possible by the affordances of the technology.

A similar thought experiment could be conducted for any field of inquiry — leading to a vast multidimensional matrix of possibilities, as we vary pedagogy, content, and technology, seeking to determine the optimal instructional solution. Contrast this rich and nuanced view of technology integration with the conventional and impoverished approach of using digital video to archive lectures! As the digital video examples indicate, the intelligent use of technology is the creative repurposing of technology — as determined by the content to be covered and the pedagogy being followed. Clearly, this multidimensional approach requires new ways of thinking about technology — moving away from static conceptualizations to those that are flexible, creative, and generative.

Policy and Practice

This complex view of teaching subject matter with technology offered by the TPCK framework has significant implications for the design of teacher education programs and educational policy, and this forms the third strand of the NTLS IX meeting. The TPCK framework can be seen as critical of technology integration approaches and programs that merely teach skills (whether related to technology, content or pedagogy) in isolation from each other. We suggest that successfully addressing the “wicked” challenge of using technology effectively in schools requires three actions:

- long-term research to identify effective uses
- practical guidance for teachers now
- communication with legislators and policy makers

NTLS and related efforts by its member associations provide a mechanism for collaboratively addressing all three.

Long-Term Research

In an era of accountability, research on effective content-specific uses of technology in schools is needed. In order to be effective, this research must be undertaken within a consistent framework rather than on an ad hoc basis. A research monograph with illustrations of effective use in each content area is being developed by NTLS participants to guide future efforts. In a parallel effort, the American Association of Colleges for Teacher Education (AACTE) is sponsoring publication of a *Handbook of Technological Pedagogical Content Knowledge for Teaching and Teacher Educators* (Colbert et al., 2007).

Research initiatives that match the affordances of technologies to the pedagogical goals of specific content areas are needed. Identification of effective practices related to TPCK requires that professionals with technological expertise collaborate closely with pedagogical and content knowledge specialists to amplify the pedagogical practice of teachers by matching technological affordances with the needs of each content area.

Practical Guidance for Teachers

Technology and emergent media are rapidly finding their ways into society and schools. Three quarters of US schools now subscribe to video streaming services. Schools are rapidly acquiring interactive whiteboards and projectors for the classroom. Research is needed to guide future use, but recommendations are also needed to guide use of current and emergent technologies based on our best understanding of the needs of each discipline at this time. Teachers cannot be expected to set these tools aside while waiting for perfect understanding of best use to develop.

The National Educational Technology Standards for Teachers (NETS-T) are being revised this year. Since it will not be possible to base the next round of revisions on definitive research, the best thinking of each discipline should be incorporated into the updated standards. NTLS provides a mechanism for the technology committees of participating associations to develop recommendations.

NTLS representatives previously developed a practitioner's guide, *Teaching With Digital Images*, published by the International Society for Technology in Education (ISTE). (This handbook has remained in the list of the ISTE's top fifteen best-selling books, suggesting a sustained interest in this area by teachers and technology coordinators.) A companion volume, *Teaching With Digital Video*, will extend this series with illustrations of applied classroom uses in each content area, specifically employing TPCK as a focus in the manner described earlier in this editorial.

Communication With Legislators and Policy Makers

Ultimately, the ability to enhance schools and schooling on a widescale basis depends upon effective communication with external groups such as legislators and policy makers. These groups determine levels of funding needed to support ongoing research and also develop the policies that determine which approaches are widely implemented in schools.

Recent Congressional hearings focused on ways in which educational uses of technology may affect global competitiveness. Communicating the connection between deep understandings afforded by content-specific approaches and global competitiveness can be challenging. Communication is perhaps the area in which educators representing instructional technology have been least effective. However, it is essential for advances in research and implementation of effective innovation in schools.

Recognition of the need for external communication is the reason the associations represented by NTLC choose to meet in Washington, DC. Subsequent legislative advocacy events sponsored by AACTE and ISTE (among others) provide continuing opportunities to build upon directions established through interdisciplinary dialog. These collaborations allow groups with various perspectives and expertise to coalesce over emerging issues that could shape the future of educational technology and schools across the US and throughout the world.

Conclusion

You can participate in this dialog in several ways. Sessions will be organized at the annual meetings of the professional associations with which NTLC is affiliated. Ongoing dialog and communications will also be held on the SITE Blog (http://www.siteblog.org/?p=96). Finally, we will publish commentaries that build upon and extend this dialog in future issues of the CITE Journal. We invite submission of short commentaries (one to three pages in length) that advance this dialog.

Guidelines for best practice within the framework of TPCK, based on solid research on learning outcomes in classroom use, are needed to realize the potential of technology. Recommendations and directions emerging from this year's summit will provide a starting point for actions in three areas: long-term research, practical guidance for teachers, and communication with external audiences. Dialog among these groups will ensure diverse perspectives needed to address the "wicked" challenge of using technology effectively in schools.

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Note:

[1] The following associations are currently represented in the NTLC (in alphabetical order):

American Association for Colleges of Teacher Education (AACTE)
Association for Mathematics Teacher Educators (AMTE)
Association for Science Teacher Education (ASTE)
Association of Teacher Educators (ATE)
International Society for Technology in Education (ISTE)

National Association of Early Childhood Teacher Educators (NAECTE)
National Council for the Social Studies-College and University Faculty Assembly (NCSS-CUFA)
National Council of Teachers of English-Conference on English Education (NCTE-CEE)
Software Information Industry Association (SIIA)
Society for Information Technology and Teacher Education (SITE)

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