Guidelines about specific situations and specific ways in which specific technologies are of significant pedagogical benefit

(With case studies from science education)

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PREAMBLE

Teachers should **not** simply assume that computers and other new technologies are good for education. Our professional development should **not** try to maximize the technological tools you master in the time available.

Instead, in learning about computers and technology in education, educators need to:

> **a. Make educationally justified and sustainable choices of when and how to integrate technologies, and**
>
> **b. Plan to learn through ongoing Professional Development how to use the technologies you decide to adopt or adapt.**

In this spirit, our efforts should be addressed at becoming acquainted with using specific computer-based tools, understanding the ideas behind them, evaluating their effectiveness, and developing guidelines about **specific situations and specific ways in which specific technologies can be of significant educational benefit.** The guidelines presented in this site differ, therefore, from technology standards, which mostly accept that computers and other new technologies are good for education and focus attention on teachers' acquisition of technological proficiency.

The guidelines are illustrated with cases from secondary and college-level science education. Comments, corrections, and additions welcome (email).

(Additional preamble or Skip ahead to guidelines)

Additional objectives

It is important to acknowledge the context in which educators are having to develop their capacity to use technology effectively in education. Although the information potentially available to anyone with internet access is rapidly expanding, knowledge can be lost in information (as the poet T. S. Eliot observed).

We need to provide tools for ourselves and for students that genuinely enhance learning. Among other things this means -- as always in education -- addressing the diversity of students' intelligences, backgrounds, and interests. In this multi-faceted endeavor, teachers trying to keep up with best practices will find many unevaluated claims and unrealistic expectations, controversy, uncertainty, and rapid change.

In the area of educational technology, therefore -- even more so than in others areas of education -- teachers need to:

> **c. Develop Learning Communities in which we help each other to learn about learning and think about change**
>
> **d. Understand and Respond to the Push for Teachers to Use Educational Technology**
>
> **e. Examine the Wider Social Changes Surrounding Computer Use Technology**

In summary, professional development in the area of technology in education should enable educators to better fulfill the needs of your school, community, or organization; address the information explosion; adapt to social changes; and collaborate with others to these ends. (Further notes on objectives b-e)

GUIDELINES

With the objective in mind of making educationally justified and sustainable choices of when and how to integrate technologies (objective a), these guidelines emphasize the following general ways -- from most important to least -- that college faculty, teachers and / or students can use computers and other technologies as tools in education.

1. To extend thinking of students

a. Use computers first and foremost to teach or learn things that are difficult to teach or learn with pedagogical approaches that are not based on computers.

E.g., The unanticipated consequences in systems of feedback where there is time delay (see Case study 1a.i)

E.g., Virtual plant and animal breeding (see Case study 1a.ii)

b. Make sure that learning / knowledge-construction is happening, especially when asking students to use the internet.

Note that most existing websites are designed more to transmit information than to ensure learning.

c. Model computer use on best practices to ensure learning without computers.

E.g., if you have ways to get students to read actively, try to incorporate them in assignments that involve accessing information from the WWW.

E.g., Problem-based learning, which uses scenarios or cases to engage students in investigation and learning, building on their prior knowledge and particular interests (see Case study 1c.i).

E.g., if you have ways to maintain the interest of girls in traditionally male-identified areas of science and technology, then use them in maintaining the interest of girls in computers (see Case study 1c.ii).

d. Incorporate activities that identify constraints and keep alternative ways of thinking in mind, remembering that computers, like all tools, constrain at the same time as they enable. (see Case study 1d)

Included in such activities is looking at the history and possible future changes that computers have brought in thinking about thinking (objective e).

e. Without discounting the social and inter-personal dimensions of supporting learning (see guideline 1c), consider whether software and/or its use meet the principles of Universal Design for Learning

See http://www.cast.org.

2. To facilitate group interaction, e.g., by freeing teacher from the bookkeeping part of class activities

1a-c apply here as well.

These guidelines are evident in software from Tom Snyder Productions, whose slogans are "teaching in the one-computer classroom," and "software for teachers who love to teach (see Case studies 2a-c).

1d also applies

because pre-programmed software tend to inhibit exploration of pathways and questions that deviate from what the designers anticipated.

e. "Take away the toys."

If students remain seated in front of a computer, as is the case in computer labs, they are easily distracted from discussion and other group activities. Ways need to be found to physically separate the computer use from the group interaction.

f. Provide an explicit structure for small group interaction and peer coaching.

Training may be needed. Attention to this contributes to building the desired learning community (see objective c). (See structure of cases in Case study 1c.i.)

3. To enhance communication of knowledge

Guidelines 1a-d also apply.

E.g., Powerpoint eliminates the time it used to take to write material on a chalkboard, but chalkboards are better for making connections during class and

for acknowledging students' contributions.
In relation to guideline 1a, see Case study 3.
In relation to guidelines 1a-c, see An exemplary webportal that Margaret Waterman provides to resources for science educators, especially in biology

4. To organize a personal workstation or "virtual office"

a. Identify and address bad work habits before seeking a technical fix.

b. Assess -- either in advance of experimenting or afterwards -- whether a new use of technology will be sustainable in your real-life work situation.

See A minimal set of tools to handle my office-on-the-computer and enhance teaching/learning interactions in a sustainable way

c. Take stock of the tendency towards "Continuous partial attention" (a.k.a. multi-tasking), set limits, and make unrushed time for sustaining/sustained synchronous, face-to-face human interactions.

d. Hold yourself to high collegial standards.

E.g., Do not use email or voicemail to communicate something you are avoiding doing face to face, or that you would not be prepared to do face to face. See Internet etiquette and ethics.

5. To comply with expectations, standards, or expenditures that promote technology use without providing sound pedagogical guidelines.

a. In discussions with colleagues and administrators, emphasize guidelines 1-3 and the distinction between "COMPUTERS in education" and "computers in EDUCATION" and, similarly, between "the teaching of technology" and "the enhancement of teaching/learning through technology."

b. Initiate or participate in a needs assessment in relation to pedagogical benefits.

c. Notice that, although technology standards for teachers may refer to higher-order thinking, etc., illustrations of standards center on using technology and rarely cite evaluations that show benefits for learning the subject matter, let alone higher-order thinking.

6. To occupy students' attention while the teacher focuses on other students

a. We should minimize this! When a teacher has insufficient resources to sustain teaching/learning interaction with students, the first step should be to mobilize additional human resources.

b. Take into account which software is drill and practice, and which extends students' thinking.

CASE STUDIES IN USE OF EDUCATIONAL TECHNOLOGY in SCIENCE EDUCATION

illustrating general guidelines for use of technology for education

Case 1a.i. Unanticipated consequences in systems of feedback where there is time delay

illustrating guideline 1, Use computers "To extend thinking of students." Sub-guideline a. "Use computers first and foremost to teach or learn things that are difficult to teach or learn with pedagogical approaches that are not based on computers."

Feedback occurs when a change in one variable -- say, the message the thermostat sends to the furnace to pump out heat -- leads to a change -- the increase in room temperature -- that eventually counteracts the original message. When multiple feedbacks interact or when there is a time delay in the feedback, there are often unanticipated consequences. The best software for exploring this is STELLA, which implements the System Dynamics framework developed at MIT by Jay Forrester and made famous by the 1972 global futures modeling study, The Limits to Growth (Meadows et al. 1972). Thinking about feedback and learning how to model it using the software does not come easily for many of us (High Performance Systems 1997; Richmond 1993), but STELLA learning laboratories, such as "Food chain," provide an entry-point.

Students' thinking can also be introduced to unanticipated consequences from feedback through activities using spreadsheets, preferably preceded by a powerpoint and pencil-on-paper introduction. Two examples suitable for college or advanced secondary students:

- House heating using an unconventional thermostat
- Managing the economy

References

High Performance Systems, Inc. (1997). "Five learning processes: The role of systems thinking and the STELLA software in building world citizens for tomorrow," in STELLA: Introduction to System Thinking Guide. Hanover, NH: High Performance Systems.
Meadows, D., D. L. Meadows, J. Randers and W. W. Behrens (1972). The Limits to Growth. New York, NY: Universe Books, 157-197.
Richmond, B. (1993). "Systems thinking: Critical thinking skills for the 1990s and beyond." System Dynamics Review 9(2): 1-21.

Case 1a.ii. Virtual plant and animal breeding

illustrating guideline 1, Use computers "To extend thinking of students." Sub-guideline a. "Use computers first and foremost to teach or learn things that are difficult to teach or learn with existing -- not computer-based -- pedagogical approaches."

Real plant and animal breeding requires a lab, materials, time, and practical experience. BioQuest Genetic Construction Kit (GCK) is a no-frills program from the mid-80s that allows students to explore fruitfly breeding and Mendelian genetics in a virtual lab. GCK follows the 3Ps model of student learning (Peterson and Jungck 1988) involving Posing problems (how to cross flies to expose the genes involved), Problem solving (how to explore, experiment, record results, analyze them and proceed accordingly), and Peer Persuading (to show you really understand).
The 3Ps model has been implemented in GCK and a range of biology education software compiled by the BioQuest consortium at Beloit College, Wisconsin and is promoted through their newsletter and summer reisdential workshops for high school and college teachers. Bioquest "encourage[s] the use of simulations, databases, and tools to construct learning environments where students are able to engage in activities like those of practicing scientists."

- Guide to a GCK lab
- Email reflection after running the GCK lab on the possibility of adding two Ps -- select Phenomenon and detect Patterns -- before the 3Ps so that students have a fuller experience of being a scientist.
- Publications based on more experience in using the GCK software: Cartier and Stewart (2000), Eisenhart and Finkel (1988)

References
Cartier, J. L. and J. Stewart (2000). "A modeling approach to teaching high school genetics." BioQuest Notes 10(2): 1-4, 10-12. Eisenhart, M. A. and E. Finkel (1998). "Learning science in an innovative genetics course," in Women's Science: Learning and Succeeding from the Margins. Chicago: University of Chicago Press, 61-90.
Peterson, N. S. and J. R. Jungck (1988). "Problem-posing, problem-solving, and persuasion in biology." http://www.bioquest.org/note21.html

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Case 1c.i. Problem-based learning, which uses scenarios or cases to engage students in investigation and learning, building on their prior knowledge and particular interests

illustrating guideline 1: Use computers "to extend thinking of students," Sub-guideline c. Model computer use on best practices to ensure learning without computers."
and guideline 2: Use computers "to facilitate group interaction"

Lifelines Online (LLOL) develops case-based teaching materials for two-year colleges that should be readily adaptable for upper level high school biology courses.

> In addition to 40 cases in the areas of Anatomy and Physiology, Cellular Chemistry, Ecology & Environmental, Microbiology, Molecular Biology & Evolution, Reproduction & Genetics, and Zoology,
> LLOL provides guidance on Planning for Case Based Learning, Generating Ideas for Cases, Writing the Case, Assessing Cases for Learning and Teaching, and Sharing Your Cases.
> Note: PBL cases involve substantial investigation and group interaction that is notdependent on computers, but are included in these case studies in the use of

educational technology because most PBL cases now make good use of the internet and other computer tools.

Case 1c.ii. GenTech's "Einstein's Sisters" project to maintain the interest of middle school girls in traditionally male-identified areas of computer use.

illustrating guideline 1: Use computers "to extend thinking of students," Sub-guideline c. Model computer use on best practices to ensure learning without computers."
E.g., if you have ways to maintain the interest of girls in traditionally male-identified areas of science and technology, then use them in maintaining the interest of girls in computers

Einstein's Sisters project (1997-99) worked with a small group of girls separate from boys and involved discussions about their views of technology as well as their changing image as computer users. Female parents and teachers were also helped. After the girls had gained confidence, they went on to teach peers.

- video clip
- GenTech website, with links to the research motivating the project
- theoretical article by de Castell et al.

References
de Castell, S., M. Bryson and J. Jenson (2001). "Object lessons: Critical visions of educational technology." http://www.educ.ubc.ca/faculty/bryson/ObjectLessons.html (viewed 8 Mar. 2001).

Case 1d. Activities based around Computer Projections of Population Growth

illustrating guideline 1: Use computers "to extend thinking of students," Sub-guideline d: Incorporate activities that identify constraints and keep alternative ways of thinking in mind, remembering that computers, like all tools, constrain at the same time as they enable.

Word documentdescribing a class involving pencil and paper, use of spreadsheets, class simulation, discussion, and textual interpretation.

Case 2a. Software from Tom Snyder Productions, whose slogans are "teaching in the one-computer classroom," and "software for teachers who love to teach"

illustrating guideline 2: Use computers "to facilitate group interaction... by freeing teacher from the bookkeeping part of class activities"

- Tom Snyder Productions website
- Decisions, Decisions activity on the Environment The instructions and booklets that accompany the software result in more structured activities than problem-based learning (see Case 1c.i), but there is ample scope for students to explore a range of options and viewpoints on the case.

References

Snyder, T. (1994). "Blinded by science." The Executive Educator (March): 1-5
Tom Snyder Productions (n.d.). Great Teaching with Technology: Resource Guide.

Case 3. Science visualization applets and software

illustrating guideline 3: Use computers "to enhance communication of knowledge" with an emphasis on "teach[ing] or learn[ing] things that are difficult to teach or learn with pedagogical approaches that are not based on computers."

Steve Ackerman, of the UMB Biology Dept., has assembled freeware and files for his students that help them visualize, for example, the 3D structure of biological chemicals -- something that is difficult to demonstrate on a 2D board.

Principles of physics illustrated on the WWW using interactive java applets.

Virtual animal dissection software. If dissection materials are too expensive or students resist dissection of animals, then virtual dissection software offers a substitute (e.g., Dissection works).

InterActive Physiology-- exploration of physiological concepts and processes.

Bookmarks to active learning and visualization sites

NOTES ON THE USE OF EDUCATIONAL TECHNOLOGY

accompanying general guidelines for the use of educational technology and case studies

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PROFESSIONAL DEVELOPMENT

Consider objectives b to e in turn:

b. Plan to learn through ongoing Professional Development how to use the technologies you decide to adopt or adapt

Administrators have often allocated funds for new software and hardware and promoted new initiatives to promote computers in education without providing teachers the training, support, and opportunities for ongoing professional development they need to use those purchases well and keep up with initiatives (Becker 1994). In order to address this imbalance the first goal of any course should be to engender in teachers a commitment to and capacity for **ongoing professional development** (PD).

c. Develop Learning Communities in which we help each other to learn about learning and think about change

PD is like a journey in that it takes us into unknown areas or allow us to see familiar areas in a fresh light; involve risk; require support; create more experiences than can be integrated at first sight; and yield personal changes. In this sense, PD is also personal development and it is essential from the outset to work on building learning communities (see Appendix 1 for more on PD learning communities). In a PD Learning Community we can learn a lot from each other and from teaching others what we know (see Appendix 2 on Learning to use new tools). We can also transfer this learning community model into how we help students learn and into how we find technology "mentors" to guide and support our future, self-directed learning.

d. Respond to the Push for Teachers to Use Educational Technology

The push for teachers to use educational technology often means we try to bring computers into teaching without a clear idea of pedagogical advantages and of ways to ensure learning happens and knowledge is gained. We should be able to respond to the push with more discrimination and to influence decision-making if we:

> a) develop guidelinesabout specific situations and specific ways in which specific technologies are of significant pedagogical benefit;
> b) identify questions that need to be researched (or that we need to locate the up to date research on);
> c) evaluate critically the stated reasons given for the push; and

d) understand the less-often-discussed reasons (social, historical, commercial, administrative).

(See Appendix 3 for warm-up, critical thinking exercise.)

e. Examine the Wider Social Changes Surrounding Computer Use

To be creative and critical about the use of technological tools we should consider possible future changes in computers and related technology in society at large -- many of these will feed into education and into our lives and those of our students. A toolkit for thinking about these visions of the future would include themes to interpret where we have come from (the history of computers in society, Edwards 1996) and alternative possibilities for where we might be going. As Joseph Weizenbaum, author of Computer Power and Human Reason responded, when asked if computers could one day replace teachers, "Yes, computers could to that, but why would you want them to?"

References

Becker, H. J. (1994). "A truly empowering technology-rich education‹How much will it cost?" Educational IRM Quarterly 3(1): 31-35.
Edwards, P. N. (1996). The Closed World: Computers and the Politics of Discourse in Cold War America. Cambridge, MA: MIT Press.

APPENDICES

Appendix 1
Premises of Professional Development Learning Community

("We" refers to teachers and their instructors; "You" refers to teachers)

1. We know more than we are able, at first, to acknowledge.

2. There is insight in every response.

3. Our initial conclusions may change, especially about what you, other teachers, your students, and your schools are capable of -- Be open for surprises.

4. Professional Development is like a journey into unknown areas or allowing you to see familiar areas in a fresh light. It involves risk; requires support; creates more experiences than can be integrated at first sight; yields personal changes. Thus the need for PD to take place in a Learning Community.

5. Small group work: When a person is heard, they can better hear others and hear themselves. This causes us to examine decisions made in advance about what the other people are like, what they are and are not capable of. The aim of working in small groups is to keep us listening actively to each other, foster mutual respect, and elicit more of our insight.

6. What we come out with should be larger and more durable than what any one person came

in with; the more so, the more voices that are brought out and energies mobilized by the process. In particular, the experience should result in your being engaged in carrying out/carrying on the plans you develop.

7. There is too much for us to deal with in our lives and teaching, so course work has to be designed to be like a natural part of what you, as teachers, are already doing, rather than extra chores.

8. Inspired by the National and State Curriculum Frameworks/Standards, PD should promote sound, considered standards for
Professional development for teachers
Use of educational technology in teaching
Assessment of student progress
Curricular frameworks and content
Engagement with the larger system shaping and supporting use of technology in education.
[ISTE National Educational Technology Standards for teachers]

9. It is expected and understandable that you will choose at some point(s) to downplay sound standards and respond instead to pressures to focus on the test-driven content standards.

10. There is too much in the national and state standards, so you should select a subset of the standards (or components of standards, or other lessons from sessions) that you want to focus on at any time (say, 6-10). (You should be prepared, however, to adjust your focus/subset as time goes on.)

11. There is too little in the national and state education standards, in the sense of not telling you what to do in your lesson planning and classes. A learning community should enable you to ask for help and support during this course in making the translations of standards into classroom practice. You should also be able to develop relationships that will enable you keep getting help and support when the course is over.

12. We can approach any course or PD experience as a work-in-progress. Instead of harboring criticisms to submit after the fact, we can find opportunities to affirm what is working well and suggest directions for further development.

Others (to be added as they emerge and we articulate them)....

Appendix 2. Learning to use new tools

1. Acknowledge the social and affective dimensions of your learning, whatever learning preference you have.

2. Take the opportunity to get introduced to -- not proficient in -- more technologies than you could adopt. Learn about what each one is supposed to do and about what training, time, and support you would need. Then, taking account of guidelines in Section B, you can make sound decisions about whether, when, and how to develop more expertise in the technologies. (See also Appendix 6: Criteria for evaluating software.)

3. When you decide to go ahead and develop practical proficiency with any particular technology or software, before you sit at the computer:

a. Make sure you have a task that motivates you to persist in learning the software.
b. Design your work on paper, including the kinds of steps you need to do.
c. Arrange assistance from someone more advanced in using the software.
d. Arrange convenient access to a computer with the software installed.

Appendix 3. Warm-up critical thinking exercise on the push for technology in education

The "old debate about whether we should have computers in schools [is] the wrong question. The question is, how do we use computers and technology to improve schools and learning?" (Keith Krueger of the Consortium for School Networking, quoted in New York Times, 5 April 2000). Consider the following reasons that have been suggested for why Krueger and others who express similar sentiments want us not to revive the "old debate" and ask "whether we should have computers in schools":

a. They cannot supply a ready answer.
b. Their organizations benefit from the adoption of technology in schools so they do not want people questioning that.
c. Computers were pushed into schools by corporations and policy makers who did not have a ready or well-supported answer.
d. If teachers, parents, and administrators evaluated the arguments for computers in schools and the costs and benefits to date they might slow down the further adoption of technology.
e. The forces that have pushed computers into schools and squelched questions about the pedagogical value are too powerful to resist.
f. It would require more time than the average teacher has to challenge effectively the forces that have pushed computers into schools and squelched questions about the pedagogical value
g. Given that computers are now in schools, we should spend our energies accommodating creatively.
h. Given that computers are ubiquitous in society, our students need to learn with them in schools.
i. They do not see that the debate on the first question draws attention to many issues about educational change that are also relevant to people asking Krueger's question.
j. The answer to the first question is obviously yes and we should not need further justification.
k. There are so many examples of pedagogically effective use of computers that there is little to learn from the pedagogically ineffective uses that were the unfortunate consequence of people pushing computers into schools on the belief that the answer to the first question was yes.
l. Other? (Please add your own suggestions.)

Identify which reasons you:

i) dis/agree with;
ii) know of evidence to support to support/challenge (and what kind of evidence); and
iii) think warrant further investigation (and what kind investigation).

Appendix 4. A proposed minimal educational technology toolkit

See a day in the office using my proposed minimal educational technology toolkit in the pursuit of sustainably enhancing teaching/learning interactions

Appendix 5. Internet etiquette and ethics

Appendix 6. Criteria for Software/CD-ROM evaluation
(Adapted from "Great Teaching with Technology," Tom Snyder Productions)

1. Easy to install
2. Documentation thorough and easy to understand
3. Good sound quality
4. Enhanced by the use of Color
5. Uses standard keyboard and mouse
6. Uncluttered screen
7. Simple and consistent commands to navigate
8. Screens easy to access, clear, and easily found by new users
9. Grade level appropriate
10. Flexible printing
11. Can be saved to a disk
12. Accurate data
13. Depth to content data
14. Free of gender, race, religious and other biases
15. Unique content, not available in print or other media accessible to schools
16. Graphics and sound meaningful
17. Can be used with more than one discipline
18. Has supporting materials or teacher's aids
19. Supports or enhances curriculum
20. Reasonable price
21. Can be used on a network
22. Stimulates student imagination and curiosity
23. Will make children think
24. Includes interactive component
25. Can be integrated into specific units in the curriculum.