Research Summary

# DIGITAL TECHNOLOGIES IN MATHEMATICS AND SCIENCE EDUCATION

**In support of *This We Believe* characteristics:**

- Multiple learning and teaching approaches that respond to student diversity.
- Relevant, challenging, integrative, exploratory curriculum.

Educational technologies are those that are used "as a "tool" to enhance the teaching and learning process across all subject areas … dealing primarily with information and communication technology centered around the didactic practice of using technology to improve the teaching and learning process" (Dugger & Naik, 2001, p. 32). In an earlier definition, the Association for Educational Communications and Technology (AECT) framed educational technology more broadly as "theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning" (Seels & Richey, 1994). Of particular interest here are educational technologies that are used in mathematics and science education in the middle grades.

**Why use educational technologies in mathematics and science classrooms?**

- Technology integration is written into national education standards:
  - The National Educational Technology Standards (NETS) describe required proficiency in both technologies for learning and technologies that increase productivity.[1]
  - The National Science Education Standards (NSES) for grades 6–8 link technology use to inquiry-based learning pedagogies.[2]
  - The National Council of Teachers of Mathematics (NCTM) addresses technology integration within their Principles and Standards for School Mathematics.[3]
  - The Individuals with Disabilities Education Act (IDEA) requires special education services that include assistive technology.[4]
- Technology integration, when combined with appropriate pedagogies, provides additional opportunities for learning and understanding.
  - Technologies, if used in pedagogically sound ways, can make the learning experience more relevant, challenging, integrative, and exploratory (i.e., Guerrero, Walker, & Dugdale, 2004; Nicol & Boyle, 2003).
  - Technologies can support authenticity in problem-solving contexts (Chinn & Malhotra, 2002).
  - Technologies can become cognitive tools in learning settings (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000; Liu & Bera, 2005).
  - Technology tools successfully support problem-based and project-based inquiry models (Barron et al., 1998; Gertzman & Kolodner, 1996; Koszalka, Grabowski, & Kim, 2002; Liu & Bera, 2005; Solomon, Allen, & Resta, 2003; van Haneghan et al., 1992).
  - Technologies facilitate connecting the in-classroom experience with the out-of-classroom world, an important aspect of creating meaningful learning environments (Bransford, Brown, & Cocking, 2000; Dede, 2004; Fox-Gliessman & Kerski, 2005; Howes, Hamilton, & Zaskoda, 2003).
  - For students with disabilities, assistive technologies may be the only means for interaction within a learning context (Staples & Pittman, 2003).

**Which educational technologies are used frequently in constructivist mathematics and science classrooms?**

Rather than attempting to list all educational technologies currently in use, this review is limited to the arguably most frequently and successfully employed technological meaning-making tools in science and mathematics classrooms.

- In a broad sense, virtual realities include microworlds, (Dede, 2004; Dede, Salzman, & Loftin, 1996; diSessa, 1986), modeling and visualization tools (Patrick, Carter, & Wiebe, 2005; White & Frederiksen, 1998), and simulations (Chinn & Malhotra, 2002; Kim, Jackson, Yarger, & Boysen, 2000). Notable examples are problem-based virtual environments, such as hypermedia, including *Alien Rescue*[5] (Liu & Bera, 2005), and LeTUS curricula (Dede, Honan, & Peters, 2005; Krajcik, Marx, Blumenfeld, Soloway, & Fishman, 2000; Marx et al., 2004; Solomon et al., 2003), and *The Geometer's Sketchpad*, a mathematical modeling environment (Flores, Knaupp, Middleton, & Staley, 2002; Garofalo et al., 2000).

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- Handheld technologies include PDAs (Cwikla & Morse, 2005; Goldman et al., 2004; Parr, Jones, & Songer, 2004; Roschelle, 2003) and calculators. Both are frequently used in connection with probeware (Garofalo et al., 2000; Guerrero et al., 2004; Reid-Griffin & Carter, 2004). Calculators may also be combined with the TI-Navigator system, a wireless two-way feedback system, and used in participatory simulations (Abrahamson, Owens, Demana, Meagher, & Herman, 2003; Naismith, Lonsdale, Vavoula, & Sharples, 2004; Roschelle, 2003). An additional wireless handheld technology that has grown in popularity exists almost always as a one-way feedback tool: classroom response systems (Fies & Marshall, accepted).

**What are the benefits of using these educational technologies in constructivist mathematics and science classrooms?**

- Student engagement and motivation increase in connection with technology-supported and learner-centered investigations (Dede et al., 1996; Flores et al., 2002; White & Frederiksen, 1998).
- As a result, these investigations bring about improved qualitative understanding and mathematical or scientific reasoning (Goldman et al., 2004; Parr et al., 2004; White & Frederiksen, 1998; Wiske, Franz, & Breit, 2005).
- Students benefit from dynamically linked multiple representations by having a variety of ways to interact with concepts (Dede et al., 1996; Flores et al., 2002; Garofalo et al., 2000; Patrick et al., 2005; Roschelle, Kaput, & DeLaura, 1996).
- Classroom response systems, participatory simulations, and PDAs can provide graduated levels of anonymity and immediate feedback that benefits both teachers and learners (Fies & Marshall, accepted; Naismith et al., 2004; Roschelle, 2003).
- While tools that support cognitive processing and share cognitive load are important early in the problem-solving process, tools that support cognitive activities, hypothesis generation, and testing are important in later stages of problem-solving (Liu & Bera, 2005).

## NOTES

[1] For more information, see http://cnets.iste.org/

[2] For more information, see http://newton.nap.edu/html/nses/6d.html

[3] For more information, see http://standards.nctm.org/document/chapter2/index.htm

[4] For more information, see http://www.ed.gov/policy/speced/guid/idea/idea2004.html

[5] For more information about *Alien Rescue*, see http://jabba.edb.utexas.edu/liu/aliendb/HOME.HTM

## REFERENCES

Abrahamson, A. L., Owens, D. T., Demana, F., Meagher, M., & Herman, M. (2003, March). *Developing pedagogy for wireless handheld computer networks*. Paper presented at the annual meeting of the Society for Information Technology and Teacher Education, Albuquerque, NM.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., et al. (1998). Doing with understanding: Lessons from research on problem- and project-based learning. *The Journal of the Learning Sciences, 7*, 271–311.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school* (expanded edition). Washington, DC: National Research Council.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175–218.

Cwikla, J., & Morse, T. (2005). A middle school teacher research team: Learning about PDAs and developing a lesson. *Meridian Middle School Computer Technologies Journal, 8*(1).

Dede, C. (2004). Enabling distributed learning communities via emerging technologies, part one. *Technological Horizons in Education (T.H.E.) Online*. Retrieved July 26, 2007, from http://thejournal.com/articles/16909_7

## REFERENCES (continued)


Dede, C., Honan, J. P., & Peters, L. C. (Eds.). (2005). *Scaling up success: Lessons from technology-based educational improvement*. San Francisco: Wiley.

Dede, C., Salzman, M. C., & Loftin, R. B. (1996). The development of a virtual world for learning Newtonian mechanics. In P. Brusilovsky, P. Kommers, & N. Streitz (Eds.), *Multimedia, hypermedia, and virtual reality: Models, systems, and applications* (pp. 87–106). Berlin: Springer.

diSessa, A. A. (1986). Artificial worlds and real experience. *Instructional Science 14*, 207–227.

Dugger, W. E., & Naik, N. (2001). Clarifying misconceptions between technology education and educational technology. *The Technology Teacher, 61*, 31–35.

Fies, C., & Marshall, J. (accepted). Classroom response systems: A review of the literature. *Journal of Science Education and Technology, 15*(1), 101–109.

Flores, A., Knaupp, J., Middleton, J., & Staley, F. (2002). Integration of technology, science, and mathematics in the middle grades: A teacher preparation program. *Contemporary Issues in Technology and Teacher Education* [Online Serial], *2*(1), 31–39. Retrieved July 26, 2007, from http://www.citejournal.org/vol2/iss1/mathematics/article1.cfm

Fox-Gliessman, D., & Kerski, J. J. (2005). Technology and the study of Wildfire: Middle school students study the impacts of Wildfire. *Meridian Middle School Computer Technologies Journal, 8*(1).

Garofalo, J., Drier, H. S., Harper, S., Timmerman, M. A., & Shockey, T. (2000). Promoting appropriate uses of technology in mathematics teacher preparation. *Contemporary Issues in Technology and Teacher Education* [Online Serial], *1*(1), 66–68. Retrieved July 26, 2007, from http://www.citejournal.org/vol1/iss1/currentissues/mathematics/article1.htm

Gertzman, A., & Kolodner, J. L. (1996, July). *A case study of problem-based learning in a middle-school science class: Lessons learned.* Paper presented at the Second Annual International Conference of the Learning Sciences, Evanston/Chicago, IL.

Goldman, S. V., Pea, R., Maldonado, H., Martin, L., White, T., & the WILD TEAM. (2004). *Functioning in the wireless classroom.* Paper presented at the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE '04).

Guerrero, S., Walker, N., & Dugdale, S. (2004). Technology in support of middle grade mathematics: What have we learned? *Journal of Computers in Mathematics and Science Teaching, 23*(1), 5–20.

Howes, E. V., Hamilton, G. W., & Zaskoda, D. (2003). Linking science and literature through technology: Thinking about interdisciplinary inquiry in middle school. *Journal of Adolescent & Adult Literacy, 46*(6), 494–504.

Kim, T. K., Jackson, D. F., Yarger, D. N., & Boysen, P. J. (2000). Principles for the design and use of simulations in science learning as exemplified by a prototype microworld. *Journal of Computers in Mathematics and Science Teaching, 19*(3), 237–252.

Koszalka, T. A., Grabowski, B., & Kim, Y. (2002). *Designing web-based science lesson plans that use problem-based learning to inspire middle school kids: KaAMS (Kids as Airborne Mission Scientists).* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Krajcik, J. S., Marx, R. W., Blumenfeld, P. C., Soloway, E., & Fishman, B. (2000). *Inquiry based science supported by technology: Achievement among urban middle school students.* Retrieved October 9, 2005, from http://www-personal.umich.edu/~krajcik/AERA.outcomes.pdf

Liu, M., & Bera, S. (2005). An analysis of cognitive tool use patterns in a hypermedia learning environment. *Educational Technology Research & Development, 53*(1) 5–21.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., et al. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching, 41*(10), 1063–1080.

Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). *Literature review in mobile technologies and learning.* Bristol, GB: National Endowment for Science Technology and the Arts.

Nicol, D. J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: A comparison of two interaction methods in the wired classroom. *Studies in Higher Education, 28*(4), 458–473.

Parr, C. S., Jones, T., & Songer, N. B. (2004). Evaluation of a handheld data collection interface for science learning. *Journal of Science Education and Technology, 13*(2), 233–242.

Patrick, M. D., Carter, G., & Wiebe, E. N. (2005). Visual representations of DNA replication: Middle grades students' perceptions and interpretations. *Journal of Science Education and Technology, 14*(3), 353–365.

Reid-Griffin, A., & Carter, G. (2004). Technology as a tool: Applying an instructional model to teach middle school students to use technology as a mediator of learning. *Journal of Science Education and Technology, 13*(4), 495–504.

Roschelle, J. (2003). Unlocking the learning value of wireless mobile devices. *Journal of Computer Assisted Learning, 19*(3), 260–272.

Roschelle, J., Kaput, J., & DeLaura, R. (1996). *Scriptable applications: Implementing open architectures in learning technology*. Paper presented at the Ed-Media '96 World Conference on Educational Multimedia and Hypermedia, Charlottesville, VA.


## REFERENCES (continued)


Seels, B. B., & Richey, R. C. (1994). *Instructional technology: The definition and domains of the field*. Washington DC: Association for Educational Communications and Technology.

Solomon, G., Allen, N. J., & Resta, P. (Eds.). (2003). *Toward digital equity: Bridging the divide in education.* Boston: Allyn & Bacon.

Staples, A., & Pittman, J. (2003). Building learning communities. In G. Solomon, N. J. Allen, & P. Resta (Eds.), *Toward digital equity: Bridging the divide in education* (pp. 99–114). Boston: Allyn & Bacon.

van Haneghan, J. P., Barron, L., Young, M. F., Williams, S. M., Vye, N. J., & Bransford, J. D. (1992). The Jasper series: An experiment with new ways to enhance mathematical thinking. In D. F. Halpern (Ed.), *Enhancing thinking skills in the sciences and mathematics* (pp. 15–38). Hillsdale, NJ: Erlbaum.

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling and meta-cognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3–118.

Wiske, M. S., Franz, K. R., & Breit, L. (2005). *Teaching for understanding with technology.* San Francisco: Wiley.


## ANNOTATED REFERENCES


Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school* (expanded edition). Washington, DC: National Research Council.


The text reviews findings of learning research across fields and age groups, and proposes a framework of learning that is defined by four dimensions of centeredness. These are: (1) learner-centeredness that begins with where learners' understandings are at the onset of an instructional event; (2) knowledge-centeredness that makes use of existing knowledge structures to develop deeper and connected knowledge; (3) assessment to support learning, and specifically formative assessment practices that tap into developing understandings, provide feedback, and provide opportunities for revision; and (4) community-centeredness that includes the community of learners in the classroom as well as the community of the school and the community at large.

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Roschelle, J. (2003). Unlocking the learning value of wireless mobile devices. *Journal of Computer Assisted Learning, 19*(3), 260–272.


Wireless Internet Learning Devices (WILDs) include technologies such as response systems and PDAs that support pedagogical functionalities such as instantaneous aggregation of learner inputs. The article's focus is on three types of WILD applications: classroom response systems, participatory simulations, and collaborative data gathering. Rather than requiring wireless connectivity to sources outside of the classroom, these are based on wireless connectivity within the classroom. Learner attention is focused on contributions from within the conceptual context of the learning environment, supporting pedagogical approaches such as peer learning models.

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Wiske, S. (2004). Using technology to dig for meaning. *Educational Leadership, 62*(1), 46–50.


The author suggests the Teaching for Understanding framework as a rationale for selecting and using learning technologies. As such, technologies need to support generative topics, understanding goals, performances of understanding, ongoing assessment, and reflective collaborative communities. When they do provide such support, technologies promote more meaningful educational experiences.

## RECOMMENDED RESOURCES


Barnett, M., Harwood, W., Keating, T., & Saam, J. (2002). Using emerging technologies to help bridge the gap between university theory and classroom practice: Challenges and successes. *School Science and Mathematics, 102*(6), 299-313.

Butler Songer, N., Lee, H. S., & Kam, R. (2002). Technology-rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy? *Journal of Research in Science Teaching, 39*(2), 128-150.

Castell, S. D., Bryson, M., & Jenson, J. (2002, January). *Towards an educational theory of technology*. Retrieved October 3, 2004, from http://firstmonday.org/issues/issue7_1/castell/index.html

Cuban, L. (2001). *Oversold and underused: Computers in the classroom.* Cambridge, MA: Harvard University Press.

Kalmbacher, S. (2004). Data to action: Technology's role in accountability. *Middle Ground, 8*(2) 12–15.

O'Neil Jr., H. F., & Perez, R. S. (2003). *Technology applications in education: A learning view*. Mahwah, New Jersey: Erlbaum.

Resnick, M., Berg, R., & Eisenberg, M. (2000). Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *Journal of the Learning Sciences, 9*(1), 7–30.

Soloway, E., Grant, W., Tinker, R., Roschelle, J., Mills, M., Resnick, M., et al. (1999). Science in the palms of their hands. *Communications of the ACM, 42*(8), 21–26.


## RECOMMENDED ONLINE RESOURCES

http://www.marcopolo-education.org/home.aspx *MarcoPolo internet content for the classroom*

http://nlvm.usu.edu/en/nav/vlibrary.html *National Library of Virtual Manipulatives* (Mathematics)

http://curry.edschool.virginia.edu/go/frog/home.html *Net frog* (Virtual Frog Dissection)

http://www.energyquest.ca.gov/index.html *Energy quest*

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