National Ocean Observing Systems Educational Product Workshop
Literature Review Results

Review Question/Issue:
What does the literature say about the impact of the use of real-time or near-real-time scientific data on the learning/test scores of K-12 students?

Summary
The study of K-12 students' use of real-time scientific data (RTD), available via computers or the Internet, and student achievement in science is a neophyte field. There are numerous studies on some of these individual topics, but few that have looked at these in combination. The few studies we found that seemed to relate to our review question/issue were primarily correlation studies, not causal (there were few pre/post assessments with controls). And, some findings conflicted with others. Given this disclaimer, here's a summarized answer to our question/issue based on the evaluation and research studies we reviewed. Below this summary you'll find details on the individual papers/reports, and at the end a list of contributers and full citation of sources.

The data that most closely answer our review question came from the National Assessment of Educational Progress (National Center for Education Statistics) 2000 Science Assessment of U.S. 4th, 8th & 12th graders. The test results generally indicated that students whose teachers have them using computers in the classroom score significantly higher in science that students in classes that do not use computers. There were some differences in grade level results. Fourth graders using computers to play learning games scored significantly higher than other 4th graders; 8th graders using computers for simulations/models or for data analysis score significantly higher than other 8th graders; 12th graders using computers to collect data, download data, or analyze data had significantly higher average science scores than students who reported never doing so. In addition, more frequent use (1-2 times per month) of computers to collect data or to analyze data was also associated with significantly higher science scores than less frequent use (less than once a month). And finally, students in all three grades who reported using the Internet at home had higher average science scores than those who indicated they did not use the Internet at home.

Other studies in our literature review indicated that:

- Teaching and learning at school with technology has a positive effect on student outcomes (in particular cognitive outcomes) when compared to traditional instruction. Some studies have found that students' use of computer technology, especially for inquiry-based activities, also increases motivation and satisfaction; other studies have found little or no impact on affective outcomes.
- Some studies have found students more engaged in lessons and learning when using computers and that absentee rates fall.
- Inquiry-based online research projects can improve student learning and motivation; however, such projects must be coupled with good pedagogy, which includes an understanding of students' prior knowledge and misconceptions (so those can be confronted before new lessons occur), teacher scaffolding (facilitation of student learning), and technology use integral to the inquiry. It also helps if the inquiry is personally relevant to students.
- Internet access in classrooms does not in itself lead to better student achievement. It depends on whether or not students have computer access, whether teachers make use of that access (computers and Internet as part of classroom instruction is still rare) and how teachers/students use that access. Teachers still need training and support in the use of computers as a classroom teaching tool.
- K-12 students are not normally taught to seek understanding (they're taught to seek answers) and so data-based inquiry projects can be a challenge for many students (and teachers, too). Students need training in the use of computers as an inquiry tool rather than just an answer-seeking tool.
- Overall, there's little research about the best ways to present real-time data to K-12 students and to encourage them to mine data for meaning.

Study Details

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
review of 42 studies	• meta-analysis of CAI (computer assisted instruction) in science at secondary and college levels *Note: No specific mention of using real-time data (RTD)*	• meta-analysis to determine effectiveness of CAI on student achievement in secondary and college science education. • compared CAI with traditional instruction • all studies in U.S., and included a control	• Small positive effect for CAI use in science. • CAI more effective under particular conditions: simulation or tutorial mode, individual use. • Best as supplement to traditional rather than replacement of traditional instruction. • Teacher-developed programs more effective than commercial. • Tentatively most effective with physics.	• Bayraktar, S. (2001-2002)
15-year olds in 31 countries, n = 175,000	• analysis of Programme for International Student Assessment (PISA) survey data	• analysis to determine the relationship between technology and student achievement. • in additional to problems in reading, math & science, the survey asked questions about home and school environment, attitudes and resources at home, including computer and Internet use. • principals surveyed about school environment including resources • included Gross Domestic Product for country, demographics and socioeconomic variables	• Focus on reading and math: no significant effect for computer access at school. • Negative impact (distraction) for computer at home. • Exception: positive for Internet use and educational software at home.	• Bielefeldt, T. (2005)
review of 11 studies n = 2,343 students	• meta-analysis of CAI (computer assisted instruction)	• compared science students achievement when exposed to traditional instructional methodology to those who received traditional instruction supplemented with CAI (computer assisted instruction), in particular simulations • compared across science disciplines: general science, physics, chemistry and biology • compared across different settings: urban, suburban and rural schools	• Students receiving traditional instruction supplemented with CAI attained higher overall academic achievement as compared to those receiving traditional instruction. • CAI with traditional instruction had the greatest impact on general science students. • CAI with traditional instruction was most effective among science students in urban areas followed by those in suburban areas, and weakest among rural students.	• Christmann & Badgett (1999)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
middle school students, n = 11 teachers and 1,000+ students	• 2 weeks use of graphical multi-user virtual environments (MUVE called River City) to enhance middle school students' motivation and learning about science and society *Note: No specific mention of using real-time data (RTD)*	• studying graphical multi-user virtual environments to enhance middle school students' motivation and learning about science and society	• Biology content: students in River City (RC) improved by 32-35%, control students improved by 17%. • Inquiry content: letters written by students to mayor found RC students earned scores more than double their paper-based control peers. • Affective results: measured thoughtfulness of inquiry, a measure of metacognitive awareness; RC scored students were significantly higher. • Affective result 2: measured subscale interest in a scientific career; the gain in interest in was 5% higher for RC students. • Engagement (from interviews): teachers offered positive reports about student engagement; students expressed interest in using RC again. • Engagement 2: absentee rate decreased by 35% in classrooms with RC. • Engagement 3: swearing monitor on online chat in RC dropped from 70 to 13 instances over the 2 weeks.	• Dede et al. (2005)
California public schools	• the E-Rate program (as part of the Telecommunications Act of 1996) provides subsidies to school and library investment in Internet and communications technology (infrastructure) with the goal of increasing Internet usage in schools	• study sought to determine whether schools with higher subsidy rates made greater investments in technology than they would have without the program and, if so, whether the increase in Internet access had any impact on observed student outcomes during the period (1996-2000). *Note: Authors admit that this study measures Internet access not Internet usage and that the student achievement results could be due to teachers not using the technology.*	• By the final year of the sample period, there were about 68% more Internet-connected classrooms per teacher than there would have been without the subsidy. • Using a variety of test score results, however, they found no significant effects of the E-Rate program on student performance.	• Goolsbee & Guryan (2006)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
6th-grade students, eight pairs from 2 classes, n =16	• students engaged in four weeklong investigations (astronomy, ecology, geology, weather) with the goal of developing a solution or answer to a question they had posed	• yearlong study investigating the depth and accuracy of 6th-grade students' content understandings (via review of student-produced materials and student interviews) as well as their use of search and assess strategies as they used online resources via Artemis (via videotapes).	• Students can benefit from access to online resources when extensive teacher support and scaffolding are provided. • Prior knowledge (and misconceptions) can support or hamper online inquiries. • Students who were highly or adequately engaged developed better, more accurate content understandings, spending more time and with more complicated search strategies. • Quality of online resources was related to students' construction of content understanding. • Artemis proved to be a useful tool. • *Note: Authors state that without pre/post data and a control, the study doesn't indicate a causal link between learning outcomes and the use of online resources.*	• Hoffman et al. (2003)
n = 80 6th-grade & 86 5th-grade students	• the use of technology in a learning environment to improve higher-order thinking skills in suburban Texas school district	• treatment and comparison groups • analysis to estimate whether students in a technology-enriched classroom demonstrate better use of higher-order thinking skills than students in a traditional program • analysis to determine if attitudes towards computers differ between students in a technology-enriched classroom and students in a traditional classroom • employed the Ross Test of Higher Cognitive Processes to judge the effectiveness of curricula or instructional methodology designed to teach higher-order thinking skills of analysis, synthesis and evaluation • employed the Computer Attitude Questionnaire to determine attitudes toward the computer	• Significant differences ($p<.01$) between the treatment and comparison group scores on Ross subtest score for both the 6th- and 5th-grade students. • No significant differences on the analysis and synthesis subtests for either grade level. • "The creation of a technology-enriched classroom environment appears to have had a minimal but positive effect on student acquisition of higher-order thinking skills" —scores were generally higher for analysis and synthesis and significantly higher for evaluation. • 6th-grade students' attitudes towards computers showed no difference between treatment and control groups, but 5th-grade treatment group scores were significantly higher on subtests measuring importance, motivation and creativity. • Teachers reported that technology-enriched classrooms differed from traditional one in that: 1) learning was more student centered, 2) environment	• Hopson et al. (2001-2002)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
		Note: Authors noted the study was limited by the population's characteristics (suburban kids) and the inability to control for the effect of personal/home computer use.	facilitated cooperative group learning, 3) student participation focused on application rather than knowledge acquisition. • Exposure to technology and training in its use results in a more positive attitude relative to computer importance—students are more likely to take control of their learning, stay focused through task completion, and pursue hypothetical solutions to problems.	*(continued)* Hopson et al. (2001-2002)
urban middle school 8th grade students, n = 33	• 8-week curriculum where science students investigate the spread of diseases based on the question "Can good friends make me sick?" • students use two technologies: Artemis, a web-based inquiry tool, and Thinking Tags, programmable individual computer badges that engage students in a participatory simulation	• classroom videotaped during lesson presentation and students' use of the two technologies; tapes analyzed for student engagement and characteristics of inquiry • informal interviews • assessment of final presentations	• Questions students posed using these technologies were mostly worthwhile and meaningful. • Students engaged with the concepts and processes of the simulation (although rarely used scientific language). • Students found Thinking Tags easy to use; they were challenged by Artemis. • Students conducted meaningful investigations, but success varied. • Students' investigations showed strong connections to the real world (their lives) and other similar investigations. • Students often did not do careful data collection or observation note taking; they also did not apply all information available to make and state conclusions. Continuing the investigation (and gaining more experience) helped resolve some of these problems. • The personal nature of the topic (communicable diseases), the integral nature of the technologies (embedded in the inquiry) and instructional support (teacher as facilitator) engaged students in meaningful investigations.	• Hug et al. (2005)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
review of 12 studies	• meta-analysis of computer-based instruction	• impact of computer use in the classroom (elementary to college to adult ed) on learning and achievement	• On average, students who used computer-based instruction scored at the 64^{th} percentile (on achievement) as compared the 50^{th} percentile scored by students under control conditions without computers. • Students learn more in less time with computer-based instruction. • Students like their classes more and develop more positive attitudes with computer-based instruction. • Computers did not have positive effects in every area in which they were studied.	• Kulik, J.A. (1994) in Schacter (1999)
summary of forthcoming review of 36 studies	• meta-analysis of computer applications in math and science	• meta-analysis of the findings of 36 studies published since 1990 which examined these types of computer applications: 1) integrated learning systems in math; 2) computer tutorials in science; 3) computer simulations in science; 4) microcomputer-based labs (including real-time data) *(Note: We're reporting only the results from the science studies here.)*	• Effect of computer tutorials in science was large enough to be both statistically significant and educationally meaningful. Average effect raised test scores by 0.36 standard deviations (equivalent to a test score boost from 50^{th} to 64^{th} percentile). • Tutorial effects on student attitudes toward instruction and subject matter were also strong and positive. • Early evaluation studies (prior to 1990) provided little evidence of improved learning with simulations. This review found that computer simulations can sometimes improve the effectiveness of science teacher, but the success is not guaranteed. • Earlier evaluation studies (prior to 1990) showed little learning advantages for microcomputer-based labs. This review also found no consistent contribution from such labs to student learning.	• Kulik, J.A. (2002)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
a 6th-grade class	• 8-week atmospheric science lesson using current imagery and online communications in a inquiry-based curricular program	• pre/post test for the entire class • individual interviews with 6 students representing three different motivation levels	• Students made significant gains in weather content knowledge as measured by written assessments. • Interviews revealed a high level of student motivation and satisfaction. • Program success likely due to: telecollaborations over the Internet with other students, studying current & meaningful issues relevant to students and time to conduct in-depth investigations.	• Mistler-Jackson & Songer (2000)
students from 2,100 U.S. schools, n = 47,000	• not evaluating a program, but assessing student achievement	• the 2000 science assessment was conducted nationally at grades 4, 8, and 12 and included representative samples of both public and nonpublic schools. • the test is organized according to two dimensions: fields of science and ways of knowing & doing science; three fields of study: earth, physical and life sciences. • the goal is to track U.S. students' academic progress over time.	• 4th-grade students whose teachers had students use computers to play learning games scored higher (significantly), on average, than 4th graders whose teachers did not. • 8th-grade students whose teachers had students use computers for simulations and models, or for data analysis scored higher (significantly), on average, than 8th graders whose teachers did not. • 8th-grade students who were not taking science performed lowest on the test. 8th-grade students enrolled in a life science course had significantly lower scores than their peers enrolled in earth science, integrated science, physical science, or general science. • 12th-grade students who reported using computers to collect data, download data, or analyze data had significantly higher average scores than students who reported never doing so. More frequent use (1-2 times per month) of computers to collect data or to analyze data was also associated with significantly higher scores than less frequent use (less than once a month).	• National Center for Education Statistics, NAEP, 2000 Science Assessment

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
CONTINUED FROM ABOVE	*see above*	*see above*	• 12th-grade students who had taken first-year biology, chemistry or physics during high school had significantly higher scores than students who had not. Performance of 12th-grade students didn't differ by whether or not they had taken general science. • Students in all three grades who reported using the Internet at home had higher average scores than those who indicated they did not use the Internet.	• National Center for Education Statistics, NAEP, 2000 Science Assessment
review of 219 studies	• meta-analysis of research studies from 1990 to 1997	• to assess the effect of technology on learning and achievement across all learning domains and all ages of learners	• Students in technology rich environments experienced positive effects on achievement in all major subject areas. • Students in technology rich environments showed increased achievement in preschool through higher education for both regular and special needs children. • Students' attitudes toward learning and their own self-concept improved consistently when computers were used for instruction. • The level of effectiveness of educational technology is influenced by the specific student population, the software design, the educator's role, and the level of student access to the technology.	• Sivin-Kachala (1998) in Schacter (1999)

Audience	Program Description	Eval/Research Goals & Methods	Findings/Results	Source
6th-grade science students, n = 8 in four dyads	• study of students as they used the Web to carry out an inquiry-based assignment (an online activity focused on ecology) that spanned five class periods	• two pairs of students in each of two classes were observed (via video & audio recording) during their time online; students were asked to talk about what they were doing (although there was no formal "think aloud" protocol) • plus informal conversations and a review of student journals	• Students use Web technologies easily but simplistically, working on three "personal" goals: finding the perfect Web page, getting a small, right number of hits, & finding a ready-made answer. • Information seeking (the lesson's goal) is a complex and difficult process for these students (something they're not used to doing). • Developing students' understanding of content through use of the Web is a challenge for students and teachers especially given the variety of content on the Web. • Factors influencing students' actions online were: pedagogical approach employed by the teacher and corresponding degree of support received during the inquiry, both online and offline.	• Wallace et al. (2000)
42 studies, combined, n = approx. 7,000 students	• varied; meta-analysis (based on a provided list of criteria) of multiple programs	• meta-analysis to estimate the effects of teaching and learning with technology on students' cognitive, affective, and behavioral outcomes of learning	• Teaching and learning with technology has a small, positive, significant ($p < .001$) effect on student outcomes when compared to traditional instruction. • The review of the 29 studies containing cognitive outcomes indicated that teaching/learning with technology had a small, positive effect on student's cognitive outcomes when compared to traditional instruction. • The review of the 10 studies containing affective outcomes indicated that teaching/learning with technology had a small, positive, non-significant effect on student's cognitive outcomes when compared to traditional instruction. • The review of the 3 studies containing behavioral outcomes indicated that teaching/learning with technology had a small, negative, non-significant effect on student's behaviors.	• Waxman et al. (2003)

Contributors

This review was developed by a committee established at the workshop, "Planning for the Future of IOOS Education: Development of national instructional materials using ocean observing systems data," held in July 2005 at MBARI in Moss Landing, CA. The paper/report reviewers were: Linda Hagelin, Monterey Bay Aquarium; Liesl Hotaling, Stevens Institute of Technology; Pauline Luther, Pinellas County Schools, FL; George Matsumoto, MBARI; Eric Simms, Rutgers IMCS; and Chris Parsons, Word Craft, who headed the committee and pulled together this document. Other committee members were Susanna Musick & Vicki Clark, VIMS; Amy Cline, University of New Hampshire; and Atziri Ibanez, NOAA.

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