The Impact of Digital Technologies on Teaching and Learning in K-12 Education

Research and Literature review
Final Report

Prepared for Curriculum Corporation

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30 July 1999

Executive summary

The review reports on the following key areas that emerge from the research literature relevant to the impact of digital technologies on teaching and learning:

- learners' perceptions of technology
- learners' attitudes and motivation
- learning outcomes
- learning activities
- teachers' perceptions of technology
- instructional strategies and practices
- access and infrastructure
- the uptake of technology by organisations and individuals
- professional development.

The review includes only findings that are derived from studies with measured outcomes, noting the lack of such investigations reported in the literature and the possible explanations for this. Major findings are referenced in a discussion of each of the key areas listed above, followed by a general discussion. An annotated bibliography containing a brief summary of relevant publications is attached.

Purpose

This review identifies and reports on current research literature investigating the impact of digital technologies on teaching and learning in K-12 education in Australia and internationally. The review focuses on reports of recent qualitative and/or quantitative studies which measure teaching and learning changes and outcomes arising from the implementation of digital technologies in this educational setting. The studies selected employ various forms of computer-based technology, including hardware, software and the Internet. Only literature related specifically to teaching

and learning was selected. Relevant literature was identified through database and on-line searching.

Features of the Literature

While there exists a significant body of theoretical and anecdotal literature on the potential benefits of digital technologies in K-12 teaching and learning, relatively few rigorous and systematic studies that investigate the impact of such technologies have been reported.

A number of authors have offered possible explanations for the shortcomings of the literature. McKenzie (1995) suggests that a lack of expertise and resources, the low value placed on research and the high demands of implementing technology programs in schools are factors which hamper thorough investigation. Johnson (1996) argues that the lack of research into the effectiveness of technology is due to an inappropriate focus on programmed instruction and poor research design and execution.

The nature of the teaching profession is such that emphasis is not placed on the communication of innovative practices in scholarly publications but rather in more informal distribution vehicles. Reports on such practices are more likely to appear in peer-reviewed sources when individual teachers or schools work in collaboration with university partners.

The lack of published studies in this area may also reflect the relative immaturity of this field of research. It may be too early in the life-cycle of many projects for participants to examine their activities systematically and critically. This may explain the high proportion of descriptive reports which tend to emphasise sharing of ideas and content, collaboration and experimentation.

Literature relevant to the topic is heavily dominated by studies originating from the United States. Specific studies that have addressed the changes associated with new computer-based technologies have focused variously on the evaluation of an intervention, particular instances of classroom applications or specific research questions. A range of qualitative and quantitative approaches have been used, providing information at various levels of detail from broad overviews to case studies. Researchers have employed a variety of data collection methods depending upon the nature of their investigation, such as web-based and paper surveys, observations of participants, student assessment and test results, self-reports from teachers, one-on-one interviews and web site analysis. These studies, however, do not yet form a connected or comprehensive body of knowledge.

Issues in Teaching and Learning

The following issues specific to teaching and learning have emerged from this review.

Learners' perceptions of technology

Little of the research identified was concerned with understanding learners' ideas about technology in general and, more specifically, about the ways it could be used in the classroom.

One of the few investigations of student perceptions is part of the Apple Classrooms of Tomorrow (ACOT) program. Tierney and colleagues (1992, see also Tierney, 1996) followed six students using computer technology during four years of high school and observed shifts in the way students viewed themselves as learners and users of computer-technology. Although each had distinctly different goals and experiences, the students became more aware of computers as a powerful tool which could help them achieve their goals and develop and communicate their ideas. They also viewed their enhanced computer skills as important for achieving future career and personal goals.

Learners' attitudes and motivation

The attitudes and motivation of learners engaged in computer-based activities, as reported by both students themselves and their teachers, has received significant attention from researchers in this area.

In a study of the attitudes and behaviour of a group of fifth grade students using the Internet, O'Hara (1998) observed increased motivation for and focus on the learning task. A follow-up attitudinal survey revealed no evidence of intimidation or frustration amongst the group, despite their limited computer experience. This finding contradicts accepted views that learners will rapidly become frustrated with a computer-based task if they feel they lack sufficient technical skill.

Teachers responding to Richards' (1996) survey of participants in Bell Atlantic's *World School Program* cite increased motivation as the most common effect of working with computer technology on student behaviour. This enthusiasm is mirrored in learners' responses with 92% of students rating the Internet as an effective learning tool.

Follansbee et. al. (1996) conducted an experiment which compared learning outcomes of project-based tasks for students with and without online access. The researchers found that students with online access became more confident in carrying out and presenting the research project.

Concerns have been raised, however, that such increases in motivation may arise from the novelty of computers in the classroom and therefore may be unsustainable in the long term. Two recent studies indicate that this may not always be the case.

From a study that followed students in the *Microsoft-Toshiba Laptop Pilot Program*, Chessler and colleagues (1998) found that high levels of enjoyment and interest were maintained through the second year of the program. In a six-year study of student engagement in technology-rich classrooms, Sandholtz et. al. (1995, 1997) found that engagement was increased and sustained under conditions which encouraged appropriate, curriculum-wide use of computers as tools.

While these results indicate that student motivation can be increased and maintained through technology-supported activities, further research is needed to develop a better understanding of the circumstances under which this occurs.

Learning outcomes

Studies concerned with investigating the impact of computer technologies on learning outcomes use a range of different measures and definitions of achievement, including results from standardised tests, class assignments and exams, and researcher and teacher observations.

For example, Denton and Manus (1995) analysed standardised test scores during the period of technology introduction in eight schools. They report a mixed picture, concluding that there is little evidence for "bold claims" of positive impact of technology on student achievement. Only some schools showed improvement over the period and this improvement was not evident in all subject areas.

The previously mentioned experiment by Follansbee and colleagues (1996), which compared learning outcomes for students with and without online access, found that students with online access produced better projects than those without. Specifically, the online access appeared to strengthen students work in terms of the measures of effectiveness of presentation, presentation of a full picture, integration of different points of view, and completeness of the project.

Similar results were found in a comparison of laptop and non-laptop students where teachers reported higher quality work from students whose use of laptop computers loaded with office software was integrated with their classroom work (Chessler et al, 1998).

In a study which followed participants in the ACOT program over a period of four years, Tierney and colleagues (1992; Tierney, 1996) observed that over time the students increasingly represented their ideas using graphical and non-linear forms. This shift was attributed to the integration of computer technology in the classroom which allowed learners to move beyond mere skill acquisition to a level of proficiency and innovation which allowed them to explore and express more sophisticated conceptions.

In one of the few studies of the effectiveness of computer-based learning environments, Williams (1999) examined the effect of expert stories on students' achievement and problem-solving ability within a hypermedia-supported authentic learning environment. She found that students using the story treatment performed significantly better than students using the non-story condition when asked to solve near-transfer (i.e. similar to the treatment) and far-transfer (i.e. not previously encountered) problems.

Richards' (1996) survey collected comments from teachers who reported improvements in the reading and writing skills and team work of their students. While indicative of the kind of impact computer technologies may have in the classroom, such evidence is largely anecdotal and further systematic investigation is necessary.

The studies identified in this review that are concerned with changes in learning outcomes as a result of technology use tend to focus on a particular aspect of the learning process, with researchers having adopted different conceptions of student achievement. Given the limited scope of these investigations, comparison between findings is problematic and the results need to be considered within the broader picture of the K-12 experience.

Learning activities

A substantial proportion of the literature reviewed reports on changes to the kinds of learning activities that computer-based technologies can facilitate for students. These would appear to indicate a change in role, with students becoming more active and independent (cf. Bernauer, 1996).

The 1995 CELT report suggests that the introduction of technology into the classroom offers new learning experiences which require learners to develop new information management skills. The authors cite literature which suggests an increased focus on project-oriented and individualised activities, but also note the lack of applications which exploit the full potential of the new technologies. A number of studies support this suggested trend.

Kaye's (1995) study of students using a networked learning environment indicates that characteristics of computer networks can support discovery-based, student-centred learning through a range of collaborative and individualised activities. Follansbee et. al. (1996) found that students with online access reported more frequent use of computers over the course of the study for the types of school work that are most closely related to a project-based unit of study (e.g. assisting with basic tasks, gathering information, organising and presenting information and creating multimedia packages).

Meghabghab and Price (1997) report that improved access to information and software resources can support a wider range of learning activities, especially for students in rural areas. Bernauer (1996) notes that the establishment of computer facilities at his school resulted in students producing their own hypermedia software, while Solis (1997) describes students' involvement in the collaborative construction of Web-based virtual environments.

Internet–based collaborative activities, during which students may work either with classmates or others beyond the classroom, receive particular attention. Wiesenmayer and Koul's (1998) survey of *RuralNet* teachers reports increased use of hands-on, project-based, investigative activities in which the Internet is used to support collaboration with others both in and outside the class. Becker (1997) describes students' collaborative involvement in writing projects with distant classes, live events such as field trips, and Internet publishing. Statistics from CCA Research's (1996) study shows increased use of and interest in technology to support distance learners.

Despite the interest in collaborative work indicated by the literature cited above, other studies suggest that this potential remains under-developed. Richards' (1996) survey of participants in Bell Atlantic's *World Schools Program* reports that information retrieval was judged by teachers and students as the most common and most effective use of the Internet, whereas project and collaborative activities were rated as less common and effective. This is reflected in the sample of school web sites examined by Barron and Ivers (1998) which found that pages contained mainly for information about the school, with few either reporting on or inviting collaboration.

Changes in learners' activities are also impacting upon organisational aspects of schools. Bernauer (1996) notes the need for longer class periods and different timetable arrangements to accommodate moves toward increased project work. Meghabghab and Price (1997) argue that older students need more time and training to complete their projects.

It is interesting to note that the majority of reports relating to learning activities arise from collaboration between university researchers and classroom teachers, rather than from teachers themselves. This is not surprising given that research plays a central role in the work of university researchers, but is generally of less importance to practicing teachers. This prevalence of university-based studies may result in only a partial picture of the impact of technology on learning activities, perhaps with a focus placed on the more innovative applications.

Another factor which complicates the development of a full picture of technology-based learning activities are variations in use at different school levels. Although Becker's (1997) survey identifies some of the different uses and trends in use, studies have tended to focus more heavily on younger students (Meghabghab & Price, 1997).

Despite indications of a shift towards project-based and collaborative learning activities, without more widespread and representative reporting no judgment can be made about the full range of technology-supported learning activities occurring in schools or the predominance of some activities over others.

Teachers' perceptions of technology

It appears that researchers have been more interested in teachers' perceptions of the technology and its use in the classroom than in those held by students.

An examination of the reflective portfolios prepared by students undertaking an educational technology field placement led Balli and colleagues (1997) to conclude that preservice teachers underestimated the sophistication of both the computer equipment available in schools and school students' ability to use computer technology. The disparity between their expectations and experiences caused a number of preservice teachers to reassess their perceptions.

Further studies note that, over time, as teachers move from anxiety over using computer technology in the classroom to increasing comfort, their perceptions and practices also change (CELT report, 1995; Bernauer, 1996).

Heflich (1996) noted differences in teachers' perceptions of technology between high- and low-access schools. Teachers from high-access schools tended to be more positive about the enhanced communication and information access offered by computer technology, while teachers from low-access schools were more concerned about how their students would manage the large amount of information available. Teachers from both high- and low-access schools were concerned about the quality and appropriateness of material sourced from the Internet.

Richards' survey (1996) highlights the difference between students' and teachers' perceptions of the Internet with only 58% of teacher rating the Internet as an effective teaching and learning tool, compared with 92% of students.

In an experiment which compared teachers' behaviour and attitudes in classes with and without online access, Follansbee et. al. (1996) found that teachers with online access appeared to have increased their personal Internet use from the beginning to the end of the study, whereas teachers without online access appeared to have made no change. Compared to those without access to the Internet, teachers with online access reported that they dealt with a wider range of information and personally learned more about the topic of focus for the study, attributing this to their access to online resources. Teachers in classes with online access also reported acquiring more information from their students than did the control teachers. Teachers with online access had more positive interactions with parents than did teachers without online access, including more positive teacher conferences, more parents visiting the classroom, and communication with parents online.

Henderson and Bradey (1999) report on the first phase of whole-school approach to technology diffusion for a distance education K-10 school in Queensland. The teachers' self-reported outcomes of this first phase included: increased confidence; improved competency in computer skills and Internet usage, particularly with search strategies; recognition of their own and others' efforts; ability to integrate CD-ROMs and the World Wide Web (WWW) as learning tools into their curriculum; using CD-ROMs and the WWW with their classes and; witnessing their students' growth and enjoyment.

These reports suggest that as technology has become more integrated into the classroom teachers' perceptions of technology and the way it can be used has changed. Such changes may be expected to influence teaching practice.

Instructional strategies and practices

The literature on changes to instructional strategies and practices somewhat mirrors the changes to learning activities – as learners have become more active and independent, teachers have taken on a more facilitative role.

Sandholtz et. al (1995, 1997) observe that the introduction of technology challenges teachers' beliefs about their role in the classroom, often prompting them to re-examine their practices. This is supported by survey data which indicates that teachers using the Internet were more likely to report changes in teaching practices, compared with non-users and those who had their students' use supervised by a media specialist (Becker, 1997).

In a later study Becker (1998) examined the changes that teachers, associated with the *National School Network*, perceived in their teaching practice and environment in relation to their use of computer software and the Internet. He found that frequent computer and Internet use is related to changes in pedagogical approaches with teachers: (1) being more willing to discuss a subject about which they lack expertise and allowing themselves to be taught by students; (2) orchestrating multiple, simultaneous activities occurring during class time; (3) defining long and complex projects for students to undertake and; (4) giving students greater choice in their tasks and the materials and resources they use to complete them.

Technology in the classroom has changed the ways in which teachers use resources, with teachers often re-packaging and re-purposing existing materials. Bernauer (1996) observed that as a result of the introduction of technology in his school many teachers were developing their own hypermedia materials. Respondents to Wiesenmayer and Koul's (1998) survey indicated that they used Internet materials as supplementary information or, less commonly, to replace a traditional text.

Observed changes in teachers' instructional strategies have also been linked with changes in their beliefs about learning. Becker (1998) found that the length of time that teachers had assigned to computer work correlated with constructivist-oriented changes in pedagogy and perceptions for middle and high school teachers, but not for elementary teachers. The time allocated to students for computer work "every week" was associated with pedagogical and perceptual changes for high school teachers, but only marginally for elementary or middle school teachers. The correlation between direct pedagogical use of the Internet and pedagogical change measures was twice the size for high school teachers as for teachers at lower grade levels. Also, secondary English, social studies, and science teachers (particularly social studies teachers) and high school teachers outside of the academic core subjects were the ones for whom a technology-based teaching approach was most closely associated with pedagogical change.

In investigating the issues and factors that influence successful, computer-based technology-using teachers' success in the classroom, Hughes (1998) found that the four teachers who were the focus of the case study held similar beliefs about technology's place in the curriculum. They taught students how to use technology for curricular ends and considered technology to be one tool among many, integrated as appropriate into all classroom activities.

In a study of teachers at high- and low-access schools Heflich (1996) found that those with high access tended to be more constructivist in their approach to teaching and learning, while those with low access tended to be more teacher-directed. While not claiming that this indicates a cause-and-effect relationship between access and pedagogical approach, Heflich argues for increased attention to this issue.

Henderson and Bradey (1999) report on the first phase of a whole-school approach to technology diffusion for a distance education K-10 school in Queensland. An important outcome of the phase saw a majority of teachers appear to change their pedagogy to integrate new ways of teaching and learning into their curriculum. They had grappled with the necessary pedagogical changes to their thinking and practice.

The studies cited here indicate that the introduction of technology may prompt teachers to re-examine and change both their teaching practice and the way they think about teaching and learning. There is some evidence to suggest a move towards more learner-centred constructivist approaches, although this may not be representative of the broader picture.

Access and infrastructure

As a backdrop to the changes in teaching and learning outlined above, a range of programs initiated by government, business and community groups has seen significant improvements in the technology infrastructure available to many schools (cf. Meghabghab and Price, 1997).

The STAR reports (1997 and 1999) provide an indication of the computer infrastructure available in U.S. schools. The results show that the numbers of computers installed has increased to a base of six million and schools are increasingly obtaining Internet access (80% of schools in 1999).

However these broad statistics belie the true picture. The STAR reports (1997, 1999) estimate that more than half of schools surveyed remain at a level of low technology, possibly reflecting a large investment in out-of-date equipment. In many schools the lack of adequate infrastructure is frustrating teachers' efforts to come to grips with the technology (Wiesenmayer & Koul, 1998).

Statistical data collected by CCA Research (1996) indicates a widening gap between high- and low-wealth districts, with significant differences in home computer ownership and use of instructional software outside school.

Little research into the effectiveness of different hardware and software environments is reported in the literature. The integration of computers throughout the school organisation and curriculum is often a stated goal of implementation programs, but trend data reported by CCA Research (1996) shows the continued dominance of computer labs (despite an increase in the number of districts with *some* computers in *all* classrooms) and greater integration of technology with only some subject areas.

In one of the few studies investigating the use of different types of hardware, the laptop study conducted by Chessler and colleagues (1998) report a range of positive effects observed in students using laptop computers in all classes, including higher quality work and improved motivation compared to non-laptop students.

The uptake of technology by individuals and organisations

The literature reviewed also identified technical and human factors which influenced the uptake of technology by individuals and organisations.

Heflich (1996) argues that the ease of access (including availability of equipment and connection to the Internet) is a determining factor in the extent to which technology is integrated with teaching and learning.

The involvement of the whole school community is emphasised by a number of authors. Particularly important is a prominent role for teachers in the decision-making process and the support of the school administration (Bernauer, 1996).

Henderson and Bradey's (1999) report on the first phase of technology diffusion in a Queensland distance education school suggests five major factors which promoted this diffusion, including: (1) a whole school approach; (2) the principal as the catalyst for change; (3) a majority of teachers committed to their professional development in the area of technology; (4) the implementation not being dependent on having all of the technology in place and; (5) collaborative professional development projects focused on pedagogy and curriculum resources.

In investigating issues and factors that influence teachers' success in using technology in the classroom, Hughes (1998) found teachers most appreciated an interpersonal relationship between the teacher and the administrator which afforded each opportunities to discuss ideas about use of technology. It was also important that schools rallied around a technology goal.

The positive outcomes reported, in this body of literature, support the whole-school approach framework for technology integration. However, this will only be confirmed by summative evaluation when there has been sufficient time for such initiatives to mature.

Professional development

Issues concerning how best to prepare teachers for integrating computer technology into the classroom are prominent in the literature.

Balli and colleagues (1997) found low levels of awareness of educational technology even among younger preservice teachers with relatively recent school experience. They argue that fieldwork placements are needed to develop preservice teachers' IT skills as the rapidly changing nature of technology means that even young undergraduates don't have up-to-date experiences with classroom technology.

The CELT report (1995) observes that the focus of staff development in schools has broadened from developing the expertise of individual enthusiasts to improving the skills of a wider group of teaching and support staff. However, the STAR report (1997) noted that only 13% of public schools reported technology-related training programs that were mandated by schools or school districts and the follow-up report (STAR, 1999) noted that only 20% of teachers felt well-prepared to integrate technology into their classroom.

Meghabghab and Price (1997) highlight the importance of the *continued* provision of training and staff development to enhance integration. Backer and Saltmarch (1999) argue teacher professional development activities focused on the use of computer-based technologies in the classroom should address issues of compensation (e.g., financial remuneration, university course credit, computer equipment or software) as a motivating factor in completion and attainment of goals and/or tangible outcomes.

Backer and Saltmarch (1999) suggest that another important factor in effective teacher professional development are programs that involve participants in the design and construction of multimedia software. This allows participants to clarify their conceptions of multimedia design and execution, the amount of time required to construct even simple multimedia projects and the steepness of the learning curve for some multimedia tools.

Henderson and Bradey (1999), reporting on the first phase of a whole-school approach to technology diffusion, describe the professional development component of the project. Activities included task-based compulsory workshops in which collaborative teams explored the pedagogy involved in evaluating and using educational multimedia software and the WWW as teaching and learning tools. Few teachers commented negatively on compulsory after-hours workshops, with many reporting that the time was more than compensated by the chance "for working together and learning together". Most teachers treated the professional development tasks seriously and professionally.

Hughes (1998) found that in terms of in-service learning the more examples and models of technology use provided, the greater chances a teacher will find one that accords with his/her curricular goals and teaching philosophy.

The technology itself, especially the Internet, may offer new opportunities for professional development through access to information, such as lesson plans and resources, and contact with colleagues (Kaye, 1996; Wiesenmayer and Koul, 1998). However Becker (1997) notes that publishing of teaching materials on the Internet remains very limited.

Rosenstein Cole (1999) investigated the use of an on-line environment to facilitate mathematics teachers' professional development. The nature and rate of participation by the teachers leads the author to suggest similar programs should: expect differing forms of on-line participation; include lessons or other materials that keep those with differing on-line participation engaged in the process; make efforts to make the on-line component accessible to teachers in their homes and; make effort to include teachers with a variety of levels of experience.

Discussion

The picture emerging from this review of literature indicates several key areas of focus.

A number of researchers have been concerned with providing an overview of the current state of technology implementation, with particular attention to government, industry or locally funded programs. These reports, mainly from the United States, indicate increasing access to computer equipment and resources in schools. Of concern however is the widening gap between the infrastructure in high- and low-wealth areas. Another concern is the often unfounded correlation which these reports tend to draw between the school access to computer-based technology and impact or effectiveness for teaching and learning.

As professional development programs tend to accompany technology implementation, it is unsurprising to note the emphasis in the literature on strategies for preparing teachers to use the technology in the classroom. The connection between implementation and training is particular evident in studies of the whole-approach to change. This is also illustrated in Bernauer's case study (1996), in which he observes that the introduction of technology prompted organisational change, in addition to impacting upon teaching and learning. It would appear that technology integration acted as a catalyst, prompting a critical examination of practices.

Some researchers have been interested in changes in learners' attitudes and motivation as a result of using computer technology in the classroom. Findings suggest that use of computers can increase motivation and that this can be maintained over an extended period of time.

Changes to teaching and learning activities form another key focus for the literature. The general picture is of students becoming more active and independent in their learning and spending more time on project-based, collaborative and individualised tasks. This appears to be accompanied by a complementary shift in the role of the teacher to more of a facilitative, managerial approach. Access to the Internet in particular is allowing students and teachers to access more information and resources than were previously available and to communicate and collaborate with students and others outside their immediate area. This change is particularly significant for those in rural and isolated communities. While many will find this picture encouraging, there is insufficient evidence to judge how widespread such changes are.

Another issue yet to be addressed is the transition of learners between high- and low-technology learning environments. As noted earlier, the review of the literature suggests that whole-school approaches to technology integration and individualised technology-based initiatives most often take place in the early years of schooling (e.g., K-8). Until the process of technology integration extends across all grade levels, issues faced by students as they move from school environments which are rich in the integration of technology, curriculum and pedagogy (usually primary/elementary schools) into environments that are less well-developed with respect to technology (usually high schools) will be of concern. The disparity between high- and low-wealth districts noted from the literature review suggests that similar issues may also arise when students move from high-wealth, high-access environments to low-wealth, low-access environments.

Notable is the lack of research which reports on changes to learning outcomes as a result of technology implementation. While a few studies report changes in the way learners develop and present their ideas using computers, there is little evidence that indicates positive impacts on student.

The lack of evidence pointing to the effectiveness of technology-supported strategies is not surprising given the emergent nature of this field of research. As reports from this review illustrate, the time-frame for integrating computer-technology in a school is four to six years (CELT, 1995; Bernauer, 1996). Given that many schools have only recently begun to implement technology, it will take time for changes to infrastructure to emerge in changes to teaching practices and learning outcomes.

The high proportion of literature reporting upon implementation strategies and professional development activities in also indicative of the early stages of technology integration. Research studies suggest the success of the whole-school approach which seeks to involve everyone within the organisation in the change process. Implementation must also be coupled with effective professional development and training programs which encourage teachers to examine their role in the classroom and the role that technology can play, as well as provide them with examples of what can be and is being done and help them to develop technical skills.

Conclusion

A review of the recent research literature relating to the impact of digital technologies on teaching and learning in K-12 education in Australia and internationally indicates changes in a number of key areas, including teachers' and learners' perceptions, learner motivation, teaching and learning activities, learning outcomes, access and infrastructure, technology uptake and professional development.

While the relevant studies cited in this review give some insight into the ways in which technology integration is influencing teaching and learning, without a substantial inter-connected body of rigorous research a full picture cannot be drawn. This is indicative of the investigation yet to be undertaken in this emerging field.

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Backer, P. R and Saltmarch, M. (1999) Evaluation of a multimedia workshop model: Training instructors to use technology in the classroom. *Proceedings of ED-MEDIA/ED-TELECOM 99 World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications*. (pp. 516-521). Charlottesville, VA: Association for the Advancement of Computing in Education.

The authors describe the results of two years of summer workshops organized by the Mathematics and Science Teacher Education Program (MASTEP), in San Francisco Bay Area, which were designed to teach K-12, community college, and CalState instructors how to use, and how to motivate students to use, multimedia and the WWW in their classrooms. The learning approaches emphasised were resource-based learning, collaborative learning, and project-related learning. Results are based on participant feedback. The paper does not detail how feedback was collected or analysed.

Issued to be considered for professional development activities for teachers in the area of using technology in their classroom that are highlighted in the paper include:

- The notion of compensation (e.g., financial remuneration, university course credit, computer equipment or software) as a motivating factor in workshop completion and attainment of workshop goals and/or tangible workshop outcomes.
- The need to clarify conceptions regarding the nature of multimedia design and execution, the amount of time needed to devote to the construction of even simple multimedia projects and the steepness of the learning curve for some multimedia tools for those professional development programs which include multimedia design and construction by participants.

Balli, S. J., Wright, M. D. & Foster, P. N. (1997) Preservice teachers' field experiences with technology. *Educational Technology*. 37(5), 40-46.

This study examined 55 team portfolios representing the field experiences of 285 preservice teachers enrolled in an educational technology course. The participants were drawn from a group of undergraduate education majors representing elementary and secondary content areas. Most were in their early twenties with approximately 10% from older age groups. Participants had various levels of computer experience. As part of the fieldwork experience, teams of 4-6 planned and conducted a technology supported lesson in a K-12 classroom. Portfolios reporting on the experience were developed.

The researchers conducted an analysis of the students' reflective comments looking for themes and patterns which related to the following research questions:

- what were preservice teachers' reaction to the technology available in today's schools?
- what were preservice teachers' reactions to students' use of technology in contemporary classrooms?
- what impact did the field-based experience have on preservice teachers' professional development as users of technology?

The study found that many of the preservice teachers were surprised by improvements in technology since their own time at school and by the advanced skills of the school students. Some of the preservice teachers found this disparity with their expectations intimidating and challenging, causing them to confront their preconceptions about students' use of technology.

Just over half of the students indicated that their confidence in teaching with computers was enhanced by the fieldwork experience. The field-based experience helped several of the preservice teachers overcome their fears of using the technology.

Barron, A. E. & Ivers, J. S. (1998) Who's doing what on the Internet: a descriptive study of K-12 web pages. *Learning and Leading with Technology*. 26(2), 37-42.

The study sought to characterise the current state of web page publication among US school. The study sample consisted of a random selection of 3% of US sites listed on the *Web66 International School Web Site Registry*.

In particular the study sought to address these questions:
1. What states are producing the most Web pages?
2. What kinds of information do schools post on their pages?
3. What html features are included on pages?
4. Which multimedia elements are being used in school Web pages?
5. What types of links are included on school Web sites?
6. What types of school-related information are included on these Web sites?

The data collected about the sample sites indicated :

- that Hawaii had the largest percentage of schools with Web pages registered in *Web66* with 21%
- that most schools use web pages to disseminate organisational information, including their history, philosophy and population;
- little emphasis was placed upon instructional components with fewer than half of the schools surveyed publishing student work;
- use of a wide variety of features from basic text techniques through to Java and forms;
- use of simple designs with some use of media, mostly graphics and animation and;
- most external links were to local and educational resources
- publication of school-related materials such as newsletters and calendars.

The authors conclude that despite the potential for collaboration over the Internet, few schools used their web sites to make contacts with possible collaborators or to report joint projects. However, in comparison with similar 1996 data more schools were using the Web to communicate with parents. The authors suggest that as awareness of the potential of the Internet increases, schools may re-examine the function and effectiveness of their sites.

Becker, H. (1995) Baseline survey of testbed-participating schools [Available URL: http://copernicus.bbn.com/testbed2/TBdocs/surveys/Baseline_report_8_31.html], Accessed: 29 April 1999]

Becker, H. (1997) Two years of progress in the national school network schools, Paper presented at TelEd'97. Austin, TX. [Available URL: http://nsn.bbn.com/nsn_learnings/becker_teled97/overheads_explained.html, Access: 21 July, 1999]

Reports of the 1995 and 1997 surveys of school participating in the *National School Network (NSN)*. In both cases data was collected from three survey booklets targeted at the site-based network coordinator, the technical specialist and a school administrator.

The 1995 survey provides a statistical portrait of 105 of the 153 schools participating in the *National School Network* - a web-based program bringing together local schools and institutions to build knowledge collaboratively. The survey data collected focusing on characterising the technology infrastructure and use within participating institutions for the purposes of comparison with later surveys. It is hoped that such a comparison will demonstrate the changes within schools as a result of the program.

The 1997 survey collected data from:

- 58 schools participating in both the 1995 and 1997 surveys.
- Other schools that joined NSN since 1995 (or did not respond last time), 47 of whom provided retrospective reports about connectivity levels in 1995.
- 441 teachers from 151 NSN schools who reported on changes in their own teaching practice over the past several years and the role the Internet has played in these changes.

Comparison with the 1995 data indicates:

1. An increase in students using computer networks for learning (from 14 to 47%) and increased use both professionally and recreationally among staff. However, one quarter of staff still use a media person to assist with technology in their classroom.
2. Teacher use of email has more than doubled (from 25 to 59%), but student use of email remains uncommon.
3. Modest growth in participation in network learning activities. In particular, the number of students participating in collaborative writing projects with distant classes and in live events like electronic field trips has increased. More schools report at least one teacher participating in collaborative science investigations, as well, although the median number of students for those teachers has not increased as much as in the other areas.
4. By school level, the largest average increases in the distribution of all use were:
    - individual assignment use at high schools,
    - student team use at middle schools, and
    - "class as a whole" use at both elementary and high schools.

   High school teachers in particular no longer had to be the interface between students and the Internet that they had been 2 years earlier.
5. Internet publishing by teachers had increased from typically one teachers in 60% of school in 1995 to 3-4 teachers in 95% of schools in 1997. Similarly the percentage of schools in which students were publishing original material had increased from 50 to 86%, but was still limited to around 15 students.
6. By 1997, the number of schools publishing student work and linking other material to their web sites roughly matched the number that has indicated this intention in the 1995 survey. What was not accomplished as often as intended was putting teacher products on the Web--lesson plans, curriculum guides, and frameworks.
7. Those teaching with the Internet were more likely to report changes in their teaching or example greater skillfulness in managing parallel activities and having students work on longer projects. Additionally, teachers whose students are supervised by others, report most frequently having students explore topics on their own, or taking initiative outside of class (presumably with the supervision of others). In all cases, teachers who reported some form of Internet use were much more likely to also report changes in their teaching than teachers who were non-Internet users.

Becker, H. J. (1998) The influence of computer and internet use of teacher' pedagogical practices and perceptions, Paper presented at the annual meeting of the American Education Research Association [Available URL: http://www.gse.uci.edu/vkiosk/faculty/hank/aera98tpp/TechUse_Rel.2Pedagogy-NSN-.html**, Accessed: 29 April 1999].**

The paper reports on a study which aimed to answer the research questions:

1. To what extent is actual use of computer-based information and communication technologies associated with a greater likelihood of reported changed practices in a constructivist direction?
2. To what extent do teachers acknowledge the role of computer technologies in facilitating their changed practices?

The report examined data from a survey of 441 teachers employed in 151 U.S. elementary and secondary schools that are part of the National School Network (NSN) (a "testbed" research and development project sponsored by the National Science Foundation fostering Internet use in K-12 schools).

This paper examines the changes that these teachers perceived in their teaching practice and environment, in their own right, and in relation to their use of computer software and the Internet, taking into account their teaching responsibilities.

Summary of relevant findings:

- ← How long teachers had assigned computer work to students was correlated with constructivist oriented changes in pedagogy and perception for middle and high school teachers but not for elementary teachers.
- ← How long teachers had assigned computer work to students "every week" was associated with pedagogical and perceptual changes only for high school teachers -- but only marginally for elementary or middle school teachers.
- ← The correlation between direct pedagogical use of the Internet and pedagogical change measures was twice the size for high school teachers as for teachers at lower grade levels.
- ← Secondary English, social studies, and science teachers (particularly social studies teachers) and high school teachers outside of the academic core subjects were the ones for whom a technology-based teaching approach is most closely associated with pedagogical change.
- ← Frequent computer and Internet use is related to changes in pedagogical approaches in terms of (1) teachers being more willing to discuss a subject about which they lack expertise and allowing themselves to be taught by students; (2) orchestrating multiple simultaneous activities occurring during class time; (3) defining long and complex projects for students to undertake; and (4) giving students greater choice in their tasks and the materials and resources they can use to complete them.

The author argues that these data provides support for the causal relationship between technology use and pedagogical change, and not the mere conjunction of innovative teachers who happen to both use technology and develop a more constructivist pedagogy. However, the author does highlight the further questions that emanate from the data such as whether the teachers who changed their pedagogies while using computers were already inclined to teach in a constructivist manner and simply needed appropriate resources to do so. Alternatively, does regular experience in using computers in a substantial way with students and acceptance of new technologies like the Internet by itself facilitate and lead to broader pedagogical changes?

Bernauer, J. A. (1996) Technology and leadership, Paper presented at the Annual Meeting of the American Educational Research Association (New York, NY, April 8-12, 1996) (Eric document ED394503).

This paper describes the integration of technology into a school for hearing-impaired students and its impact on teachers, students and the school organisation. The author describes a particular model for implementation which is teacher-driven, involves partnerships with external funders, adopts a spiraling focus on subject areas and is support by the school administration.

Bernauer argues that the impact of technology integration after the first three years of the program was evident in the routine use of an interactive technology lab by both teachers and students to produce their own hypermedia software.

While there was some evidence of positive attitude and achievement change over the period the author argues that the limited sample makes the value of statistical analyses questionable.

Observational data indicates:
- increased student motivation;
- changes in roles for teachers and students with students becoming more active learners and teachers becoming facilitators and;
- the need for longer class periods to support increased project work.

The study also highlights increased involvement of teachers in decision-making at an organisational level and the essential role of the school administration in providing support. The author concludes that the impact of technology integration has gone beyond teaching and learning to cause organisation-wide changes within the school.

CCA Research (1996) Understanding information technology in kindergarten through grade 12, 1994-1995. Report to Respondents, Wellesley, MA (Eric document ED392391).

This report presents the findings of an annual study which surveys major technology issues in K-12 education. Data is collected from school districts representing 10.5% of K-12 enrolments in the United States. The report presents data for three surveys from 1993 to 1995.

Data relating to the impact of technology on instruction indicate:

- a continued preference for placing computers in laboratories over classrooms, but with an increase in the number of districts placing some computers in all classrooms;
- a decrease in the number of computers not connected to a network;
- an increase in integration of technology into the curriculum in several subject areas;
- a widening gap in computer ownership and use of instructional software at home between high and low wealth districts and;
- increased use and interest in technology for distance education.

Centre for Educational Leadership and Technology (CELT) (1995) America's 21st century school: Linking education reform and technology, Marlborough, MA (Eric document ED393396)

This report puts forward arguments based upon research findings and practical experiences and includes a review of the impact of technology on schools.

Publications cited indicate changes in learning due to the abundance of information which is made readily available through technology requiring learners to develop new information management skills. Technology has also delivered new learning experiences which come from new combinations of media and activities. The authors note few reports of applications which indicate the potential of the technology.

Changes to teaching cited indicate a shift in technology use away from the individual with expertise to a wider staff development effort. Studies of teacher's experiences and attitudes report anxiety over technology implementation and changes.

The report cites a number of research studies which point to effective implementation of technology over a period of 4-6 years accompanied by changes to roles and practices. Other studies cited indicate that over time as teachers become more comfortable with the technology more innovation and customisation appears, views of learning tend more towards constructivism and instructional techniques move towards more interdisciplinary, project-oriented, individualised activities.

CEO Forum (1997) School technology and readiness report (STAR).

The CEO Forum attempt to develop new measurement tools capable of more fully describing the effect of technology on learning resulted in their first report in 1997 which focused on four areas of technology integration in schools

Hardware

- In the 1996-1997 school year, the average student to computer ratio was 9:1 and the average student to multimedia capable computer ratio was 16 to 1.
- In 1995, reports suggest that nearly 60% of school computer purchases were used to replace old and outdated computers, resulting in only a marginal increase in the number of machines available to students.

Connectivity

- In 1996, only 14% of classrooms had access to the Internet.
- The percentage of schools using local area networks for instruction has increased by nearly 70% every year for the last four years.

Content

- In 1995, schools spent $6 million for online and subscription-based services. This is expected to double by 1998.
- Forty-nine percent of school districts plan to increase spending on instructional software in 1997-1998.

Professional Development

- Only 13% of all public schools reported that technology-related training for teachers was mandated by the school, district or teacher certification agencies.
- When asked to rate the greatest barriers to integrating the Internet into the classroom, 50% of teachers cited the "lack of time to train."

CEO Forum (1999) Year two school technology and readiness (STAR) report Available URL: http://www.ceoforum.org/ Accessed: 26 May, 1999].

The CEO Forum's 1999 report is a follow-up to the initial investigation the result of which was released in 1997. Measurement is focused on the numbers of computer equipment and Internet connections in schools in relation to the number of students enrolled.

Chessler, M., Rockman, S., and, Walker, L. (1998) Powerful tools for schooling: second year study of the laptop program. San Francisco: Rockman ET AL.

In the Fall of 1996, Microsoft Corporation and Toshiba America Information Systems implemented a Laptop Pilot Program at 29 "pioneer" school sites across the United States. Participating students acquired and regularly used Toshiba notebook computers loaded with Microsoft Windows and Microsoft Office software. The program was designed to demonstrate that providing every student within a classroom with access to "real world" business tools would produce substantial educational benefits by supporting learning anytime and anywhere.

During the 1997-1998 school year, an independent research organization tracked the experiences of teachers and students at selected pioneer schools during their second year of the Laptop Program. In these programs, participating students had full-time access to notebook computers both in school and at home. The second year study explored when and how the computers were used, their impact on teaching and learning, and participants' assessments of their experiences in the program. The study findings point to significant learning and student and teacher accomplishments in skill development, applications of technology for schoolwork, and improved critical thinking.

In terms of the impact on teaching and learning:

- Laptop students spend more time engaged in collaborative work than Non-Laptop students
- Teachers noted that project-based instruction has increased since the introduction of the laptops in their classrooms.
- Teachers named writing as the academic outcome or skill that has been most directly affected by use of the laptops. Some teachers said simply that writing had generally improved; others said that students were doing more writing more often.
- Teachers claimed that students' use of Internet research has increased since the project began and had an impact on the quality of students' research projects and required students to be more thoughtful about which sources they use and why.
- Teachers mentioned communication skills, including making presentations and speeches, as an academic outcome or skill that has been affected by use of the laptops.
- Teachers and students take on different roles when students have laptop; Teachers become facilitators and spend less time lecturing while students become collaborators and direct their own learning.
- Laptop students reported they use computers more frequently than Non-Laptop students to accomplish complex tasks such as finding, organizing, analyzing and communicating information. They also used computers more when brainstorming to generate ideas and collaborate with other students.

- When engaged in problem-solving activities, laptop students applied critical thinking skills more readily than non-laptop students, sought *more* information—and *more varied* information, showed greater evidence of applying higher-order-thinking skills to big-picture, strategic issues rather than to information gathering and procedural issues.

Denton, J. J. & Manus, A. L. (1995) Accountability effects of integrating technology in evolving professional development schools (Eric document ED393443).

This paper reports an analysis of standard test scores which sought to determine the impact upon academic performance by the introduction of technology systems and accompanying staff development programs. Test results of 5 337 students across all grade levels from 8 elementary and secondary schools were compared for the three year period 1993-5.

The authors conclude that the data does not support "bold" claims that the programs have positively impacted upon student achievement based upon standardised measures. The authors note that, while the overall picture is mixed, trend data indicates improvements in four of the eight sites.

Follansbee, S., Gilsdorf, N., Stahl, S., Dunfey, J., Cohen, S., Pisha, B., and Hughes, B. (1996) The role of online communication in schools: a national study. Peabody, MA: Center for Applied Special Technology

This is the final report of a study conducted in seven major U.S. cities during the 1995-96 school year. The goals of the study were: 1) to measure the effects of online use on student learning including information processing, communication, and presentation skills, and 2) to gain insights into what it takes to use online communications effectively in the classroom.

In order to evaluate the effects of online use on student learning, a unit of study was developed and taught in both experimental and control classrooms. The study included 500-600 students (year four and six) in 14 experimental classes (with online access to Scholastic Network and the Internet) and 14 control classes (without online access). All classes used curricular materials, computers, and other technologies. Only the experimental classes used online resources and activities. In addition, the experimental classrooms were divided into two levels (high and low structure groups with both groups receiving basic online training and high structure group receiving additional staff development and support for integrating online use into their curriculum).

Data collection sources included:

1) student projects to measure student learning outcomes;
2) pre- and post-study questionnaires for students (n=293) and teachers (n-28) to provide data on changes in the attitudes and behavior over the course of the study;
3) in-class observation focusing on students' involvement in different forms of investigation, collaboration, and presentation; their involvement in different types of independent and cooperative behaviors; and their motivation;
4) telephone interviews with teachers to allow them to express their opinions about what worked well, voice concerns, and make suggestions for more effectively carrying out a project-based unit of study (with and without online access) in the future;
5) online connection time spent by experimental groups was logged.

Results Summary:

1) In terms of learning outcomes based on student projects, students in the experimental classes (i.e., those with online access) produced better projects than students in the control classes. T-Tests show that mean scores for the experimental group over the control group were significantly higher for four of the learning measures: *effectiveness of presentation*, *presentation of a full picture*, *effectiveness of bringing together different points of view*, and *completeness of the project*. Also, the differences in *effectiveness of stating a civil rights issue* and the *aggregate* of scores closely approach statistical significance.
2) In terms of the low and high structure groups (i.e., more or less staff development) within the experimental classes, the results suggest that the additional teacher training and support had a counterproductive effect on student learning. However, confounding circumstances external to the study meant that the analysis of this data was inconclusive.
3) In terms of the students' perceptions measured with pre- and post-surveys, students with online access became more confident and students without online access became less confident, over the course of the study, in carrying out and presenting the research project. Both experimental and control groups became less confident in their ability to share work and participate in discussions over the course of the study. Students with online access reported more frequent use of computers over the course of the study for the types of school work that are most closely related to a project-based unit of study (e.g., help with basic skills, gather information organize and present information, and do multimedia project).
4) In terms of online connect time, no relationship was found between the amount of time classes spent online and the quality of student projects.

5) In terms of teachers behaviour and attitudes as measured with pre- and post-surveys, teachers with online access appear to have increased their use from the beginning to the end of the study, whereas teachers without online access appear to have made no change. Teachers in the experimental group, in contrast to the control group, reported that they dealt with a wider range of information and personally learned more about the topic of focus for the study and attributed this to having access to online resources. Teachers in the experimental classes also reported acquiring more information from their students than did the control teachers. Teachers with online access had more positive interactions with parents than did teachers without online access. Teachers in the experimental group reported a number of changes including more positive teacher conferences, more parents visiting the classroom, and communication with parents online.

Heflich, D. A. (1996) The impact of on-line technology on teaching and learning: attitudes and ideas of educators in the field, Paper presented at the annual meeting of the Mid-South Educational Research Association (25th, Tuscaloosa, AL, Nov. 6-8, 1996) (Eric document ED403872).

The paper reports on a study of attitudes and practices of 25 teachers from 16 states and 6 counties representing elementary, secondary and K-12 schools. Respondents were selected from an invitation posted to a popular email discussion list.

The purpose of the study was to assess the impact of online technology on teaching and learning in schools. More specifically the author poses two research questions:

1. Are teachers who use online computer technology in their classrooms more likely to exhibit practices of a constructivist teacher?

2. Which structural or sociocultural elements of school support the use of online technology in a constructivist manner?

The study investigated the impact of on-line technology upon two groups identifies in the sample:

1) teachers from schools in which technology is integrated throughout all aspects of the organisation and
2) teachers from school which offered little support for technology. Data was collected through a series of email 'interview' exchanges.

The interview questions and subsequent analysis focused upon the prevalence of constructivist approaches and the associated support requirements.

The researcher concluded that ease of access to on-line technology (including equipment, connection service etc.) was a determining factor in how integrated the Internet became in schools. While comments ranged from enthusiastic to critical, teachers in high access schools were generally more positive about communication and information tools offered by the Internet. Teachers from low access schools expressed more concern about the quality of Internet materials and their student's ability to evaluate on-line information sources.

All teachers were concerned about the availability of inappropriate material on-line. The study found that a number of teachers had constructivist views of learning (especially those from high access schools).

Responses also indicated that, in general, teachers from high access schools engaged learners in activities that were more self-directed, reporting greater enthusiasm from their students. Teachers from low access schools tended to focus more upon classroom management and tended to direct on-line tasks closely.

The report concludes that, although no cause and effect relationships were evident, the relationship between access and teaching approach was important to consider in investigating the impact of on-line technology.

Henderson, L. and Bradey, S. (1999). Getting computer information technologies used in teaching and learning: a model of technology diffusion in a K-10 school. ***Proceedings of ED-MEDIA/ED-TELECOM 99 World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications*****. (pp. 1198-1202). Charlottesville, VA: Association for the Advancement of Computing in Education.**

This paper identifies the model of technological diffusion adopted, analyses the processes, procedures, and conceptual frameworks that utilized, and evaluates the outcomes of the first year phase of a whole school approach to technology diffusion in a Pre to Grade 10 school of distance education in Queensland.

A qualitative research methodology was employed. The study utilized initial workshop evaluation, a needs assessment survey, a post 53 five point Likert Scale questionnaire, open-ended structured questionnaire, teacher project documentation (which included teacher evaluations of computer software and WWW sites as well as unit plans detailing the incorporation of their selected piece of software and WWW site into their curriculum), observational data from the teachers' presentations of their WWW project to their peers, and anecdotal evidence from the technology coordinator.

All 37 teachers (Preschool through to Grade 10; one teacher-librarian, and two Languages Other Than English) were involved in the technology project. There were five male teachers and 32 female teachers ranging in age from 22 years to 50 years. Some had been in the school for up to eight years (thus, experienced in
distance education), while six teachers were appointed from regular urban public schools to the distance education school recently. In terms of technology, most participants had little knowledge beyond word processing applications and the majority had had little experience with E-mail and even less with the WWW the initiation of the project.

Summary of the diffusion plan:

- Plan involved a two-year time-line for information technology diffusion to be the school's major economic and pedagogic focus.
- The decision to focus on technology diffusion was made a school council which included teachers
- The major input into the nature of global decisions came from the school principal who was charged with the job of operationalizing the decisions.
- The school funded equipment, such as a laptop computer with a standard suite of software for each teacher, an Internet infrastructure and online costs, and a computer laboratory for in-school camps.
- Students' families were provided the opportunity to either purchase or lease a computer and printer from the school, including the standard package of software.
- A teacher was appointed as a half-time information technology (IT) coordinator-half-time teacher. This role was a two-way conduit-facilitator between the principal and the teachers.
- The school principal made it clear to staff that the school's two year focus on the integration of technology this would involve commitment to the inservice that the IT coordinator devised.
- The school did not wait until all the staff had a laptop before commencing induction programs or appointing the IT coordinator.
- Training involved all teachers, was carried out in a multi-faceted approach and was based on a needs analysis the IT coordinator conducted with the staff to ascertain their requirements and concerns.
- In-servicing involved traditional workshops, provision for peer collaborations, mentoring, and residential workshops. The first phase of the inservicing was a series of non-compulsory workshops dealing with word-processing, spreadsheet, database, desktop publishing, E-mail, and WWW access and search skills. These were held weekly for most of the first term.
- Compulsory workshops were conducted in second term and third term to explore the pedagogy involved in evaluating and using educational multimedia software and the WWW, respectively, as teaching and learning tools. Each of these sessions involved three compulsory after-school workshops that addressed theoretical and hands-on practical issues.
- During the whole process, the IT coordinator provided "just-in-time" mentoring and support for individuals and groups as either he or the teachers saw the need.

- Teachers were offered the opportunity to work individually, in pairs, or in small groups on their curriculum units.

A summary of the findings:

- The decision to focus on technology diffusion was not perceived as a "top-down" imposition by any of the teachers.
- The majority of the teachers had taken on board their personal commitment to their re-education.
- The principal was perceived by the teachers as a necessary catalyst for change. However, 21% of the teachers (Post Likert Questionnaire) would have appreciated an increased level of direct involvement, particularly in terms of individualized praise and understanding of what they were accomplishing.
- All but four teachers supported the technology infusion in their professional lives and their teaching
- Twenty-one percent of the teachers voiced a "too much, too soon" concern in their questionnaires. They would have preferred a linear approach so that they would only have had to cope with frustrations on one level (i.e., their own computer skill progress) rather than on a number of levels (e.g., coming to grips with the pedagogic changes needed for incorporating the WWW into their teaching and technical failures).
- The teachers reported that the IT coordinator helped them develop images of "how to get there" that were tied to a workable reality.
- 93% agreed that the first phase of in-servicing was a sensible approach as it allowed the IT coordinator and other new teachers to settle into teaching at a distance and all teachers to obtain a comparable level of technology skills. It also afforded staff a welcome distance from the networking hassles. In effect, it gave the teachers valuable time to begin to internalize what the school vision would mean in its actualization.
- Few teachers commented negatively on compulsory after-hour workshops. Many reported that the time was more than compensated by the chance "for working together and learning together".
- Only four teachers and the teacher-librarian worked individually. Most opted to work in pairs for the interactive multimedia CD-ROM activity with most working as groups of three on the WWW activity. There appear to be four major reasons for their collaboration: (a) it permitted the pre-school and primary teachers to brainstorm ideas for their common grade levels while the secondary teachers collaborated in discipline areas; (b) time constraints meant collaboration allowed a reduction in individual time spent resource hunting and unit preparation; (c) it provided security through peer support; and (d), it divided the responsibility for designing units that incorporated the software and WWW site in meaningful contextualized ways.
- The teachers' self-reported outcomes included: increased confidence; improved competency in computer skills and Internet usage, particularly search strategies; recognition of self and others efforts; ability to integrate CD-ROMs and the WWW as learning tools in their curriculum; using CD-ROMs and the WWW with students and witnessing their growth and enjoyment.

- A number of teachers acknowledged their need for continued improvement due, in part, to not utilizing the skills or implementing the strategies regularly.
- There appeared to be little techno-fatigue. Three months after the first year, all but three teachers (one was indifferent) reported that they still found learning about technology and its incorporation into curriculum enjoyable.
- Most teachers treated the professional development tasks seriously and professionally. The others handed in tokenistic work.
- A majority of teachers appeared to change their pedagogy to integrate new ways of teaching and learning into their curriculum. They had grappled with the necessary pedagogical changes to their thinking and practice.

Hughes, J. E. (1998) The road behind: how successful, technology-using teachers become successful, Paper presented at the annual meeting of the American Education Research Association (San Diego, April 14).

This paper presents four case studies of the process teachers experience when learning to use and integrate technology successfully in their instructional practice to enhance student learning. Specifically, the research question addressed is, "What issues and factors influence successful, computer-related technology-using teachers' success in using technology in the modal (for technology access and support) U.S. classroom?" Success was defined by reputation indicators such having won technology and education-related awards and/or highly recommended or recognized for innovative technology projects and integration.

Interviews and observations were used to collect data from participants (Four fifth-grade classroom teachers (three male and one female teacher) from different locations in lower mid-Michigan) to understand their technology learning and use. The teachers' stories were considered the methodological unit of analysis. Data collected was used to create a "learning path" that included personal and environmental factors for each participant and then similarities and differences between participants were identified.

Summary of findings:

- For the most part, all teachers have been teaching for a long time and have been pursuing technology in their teaching for at least eight years.
- Two of four participants had a formal technology background.
- These teachers' classrooms are not technology-rich, having only a few computers available
- All the teachers have access to computer labs with the exception of Frank.
- District-sponsored inservices were valued by the participant with less technology experience but not valued by the participants who had a formal technology background.
- All perceived, to various extents, support from their school administrator

- The two teachers who had won teacher awards did not find their on-site colleagues very supportive of their attempts to use technology in the classroom. However, the two participants who were at schools where technology appeared to be a school-wide goal, perceived on-site colleagues as supportive.

Emerging patterns:

- **Administrator Support**: The four teachers in this study all reported various supports provided from their administrators, in relation to their own efforts in learning about technology. Traditional supports such as providing hardware, software and inservice opportunities were mentioned by participants, but the support these teachers most appreciated and emphasized was an interpersonal relationship between the teacher and the administrator which afforded each opportunities to discuss ideas about use of technology.
- **Philosophies for Using Technology in Education**: All four teachers held similar beliefs about technology's place in the curriculum. They taught students how to use technology in the context of having students use the technology for curricular ends. Technology was considered one tool among many that was integrated, as appropriate, into all classroom activities.
- **Role of Inservice Learning**: The more examples and models of technology use provided, the greater chances a teacher will find one that accords with his/her curricular goals and teaching philosophy.
- **Collegiality and School Technology Goals:** In the schools that rallied around a technology goal for their school, colleagues appeared more supportive of each other.

Johnson. D. (1996) Evaluating the impact of technology: the less simple answer, *From Now On*, 5(5), [Available URL: http://fromnowon.org/jan96/reply.html accessed: 26 May, 1999]

Johnson observes that despite the increasing amount of technology in schools, it is difficult to find definitive studies which show that computers have had a positive impact on teaching and learning. He argues that evaluations of the effectiveness of computers in the classroom have focused on the lower order skills associated with programmed instruction and that many studied have been poorly designed and executed.

Johnson further argues that the use of computers as an information processing and productivity tool is *the* appropriate instructional use in teaching and learning. He claims that investigation of the efficacy of these strategies is hampered by the time and effort required to implement them and the ambiguous nature of learning outcomes of these techniques.

Kaye, J. C. (1996) Characteristics of effective networking environments. Paper presented at the Annual Meeting of the American Educational Research Association, New York, NY, April 8-12, 1996. (Eric document ED394502).

This paper describes the *Model Nets* project at Los Alamos National Laboratory which sought to identify the characteristics of computer networks that have a positive impact upon K-12 learning. A positive impact was defined as those features which supported a discovery-based, student-centred approach to learning.

The study involved three-day site visits to selected schools which included interviews, focus groups, observations and document reviews. From these data a number of case studies were developed. A survey of all teachers was also carried out, providing complementary quantitative data.

The issues identified were categorised as follows:
1. technical infrastructure characteristics and practices
2. policy and implementation characteristics and practices
3. operational policies and implementation
4. teaching and learning characteristics and practices.

Issues identified in the teaching and learning category were divided into administrative, instructional and professional development sub-categories.

Administrative characteristics identified included increased use of technology for communication and record-keeping.

Instructional characteristics included the ability to archive student work into portfolios, access to a wide variety of resources, interaction with the outside world, support for independent and individualised learning, support for collaborative learning, use of networks for problem- and project-based learning and the development by learners of specific job-related skills.

Professional development characteristics revealed new opportunities for teachers afforded by computer networks.

Meghabghab, D. B. & Price, C. (1997) The impact of a technology-rich environment. In: Information Rich but Knowledge Poor? Emerging Issues for Schools and Libraries Worldwide. Research and Professional Papers Presented at the Annual Conference of the International Association of School Librarianship Held in Conjunction with the Association for Teacher-Librarianship in Canada (26th, Vancouver, British Columbia, Canada, July 6-11, 1997. (Eric document: ED412953)

The authors examine the impact of Georgia's Technology Initiative arguing that while it has led to improved access to information and changes in teaching and learning, that there is an increased gap between the "information rich" and the "information poor".

The following four major impacts are noted.

The lottery funding scheme has resulted in a significant increase in the amount of equipment in schools with other funding sources providing for associated infrastructure.

Improved access to information through media centres has reduced isolation, especially for rural areas, and brought changes to the roles of media and technology specialists. Increased access to computer equipment within laboratories or classrooms has allowed learners access to a wide range of software resources.

Those schools which provide and continue to provide teachers with infrastructure, training, staff development support and technical support exhibit more effective integration of technology in the classroom.

Students participate in a wider variety of learning activities and exhibit higher motivation for their tasks. However most of the investigation's focus has been on younger age groups, while it is becoming apparent that older learners, such as high school students, require more time and training for computer-based tasks.

The authors identify training, information access, continued funding and infrastructure as the main issues facing the implementation of technology in schools.

McKenzie, J. (1995) "Did anybody learn anything?" Assessing technology programs and the learning accomplished, *From Now On*, 5(4), [Available URL: http://fromnowon.org/dec95/simpletext.html accessed: 26 May, 1999]

In a review of professionally conducted research into the impact of technology on teaching and learning, McKenzie notes that there is little evidence to suggest improvements in learning outcomes. The author offers a number of hypotheses for this including a lack of expertise and resources in school to support evaluation, the dominance of a culture which does not support or value the conduct of research and the high demands of technology-implementation.

O'Hara, S. P. (1998) A case study of attitudinal effects of internet use in a middle school integrated science curriculum, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (71st, San Diego, CA, April 19-22, 1998) (Eric document ED417978).

This paper describes a study of the attitudes and behaviour of 95 fifth grade students taking part in a two-hour guided exploration of the Internet. Students were a mixed group of Anglo and Latino children from a rural community.

Students' behaviour was observed during the exploration session with data collected using a video recording and researcher field notes. Students' attitudes were measured three months after the session using a researcher-administered survey.

The researcher reports that the students were very focused upon the activities required and exhibited increased stimulation as the session progressed. They also seemed very excited to see information about their local area, in context with information about the rest of the world.

Students showed no signs of intimidation and quickly became competent despite little computer experience. This challenges a belief that students with little computer experience tend to find such activities frustrating.

The attitude survey showed significantly more interest in activities which involved local information and students' own choice of sites. Gender, prior experience and ethnicity were not shown to be significant factors.

Richards, F. C. (1996) The impact of the Internet on teaching and learning as perceived by teachers, library media specialists and students. Unpublished Masters thesis, Salem-Teikyo University (Eric document ED410943).

This study surveyed teachers, library media specialists and students participating in Bell Atlantic's *World School Program*. Staff and students represented many US counties and grade levels with a response rate of 35-45% achieved.

The study found that those surveyed most commonly use the Internet for information retrieval and that this activity was also regarded as its most effective use. The responses revealed much lower use of project and collaborative activities.

Staff noted that increased enthusiasm was the most commonly noted behaviour amongst students using the Internet, with some also reporting improvements in teamwork and reading and writing skills. A higher percentage of students than staff considered the Internet to be an effective teaching and learning tool: 92% compared to 58%.

Overall comments were highly positive with all but one comment in support of using Internet technology in the classroom.

Rosenstein Cole, B. (1999). Characterizing forms of on-line participation in a teacher professional development setting. *Proceedings of ED-MEDIA/ED-TELECOM 99 World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications*. (pp. 1318-1319). Charlottesville, VA: Association for the Advancement of Computing in Education.

This paper reports on experiences conducting professional development focusing on mathematics for primary school teachers in an on-line environment. The program included a system to link the participants electronically in a small group, a learning community, and throughout the United States. The author investigated forms of participation in four representative learning communities through the collection of all messages posted on each of the learning communities' electronic bulletin boards for each of four weeks spread through the 1996-97 school year.

There were a total of 271 messages collected of which 24% were classified only as statements, 13% only as inquiries, 42% only as replies, 6% as both statements and inquiries, 10% as both statements and replies, and 5% as inquiries and replies. Once the messages were classified, they were sorted by participant in order to investigate the possibility of trends in participation.

Some possible trends appeared and were used to identify seemingly different forms of participation or participation profiles. This examination suggested the existence of five distinct forms of participation: (1) the non-participant who, while enrolled in the project, did not participate on-line; (2) the participant who read and posted messages infrequently; (3) the active reader who read all or most of the messages posted to the network, but never posted their own messages or did so very infrequently; (4) the informers who read and posted actively, but all of the messages they posted were either statements or replies. This group never posed inquiries always dispensing rather than seeking information: (5) the active participants who read all or almost all of the messages posted and contributed regularly to the on-line conversation using all three message types.

Generally, in this experience, 12% of the participants fell into the non-participant category, 24% in the limited participant category, 29% active readers, 12% informers, and 23% active participants.

Preliminary results found that the most active participants were also the most experienced teachers with the active participants having a mean of 24.6 years of teaching experience while the next most experienced group were the active readers with a mean of 17.3 years. Active participants tended to have access to the on-line
system at home (44.4%) or both at home and at school (44.4%) rather than only at school (11.2%).

The author's recommendations or considerations for similar professional development programs included:

- ← Organizers should expect differing forms of on-line participation.
- ← Providing lessons or other materials may be important in keeping those with differing on-line participation engaged in the process.
- ← Efforts should be made to make the on-line component accessible to teachers in their homes. While this does not guarantee participation, it appears to contribute.
- ← Finally, effort should be made to include teachers with a variety of levels of experience and not to exclude interested, experienced teachers.

Sandholtz, J. H., Ringstaff, C. & Dwyer, D. C. (1995) Student engagement: views from technology-rich classrooms. ACOT* Report #21. Cupertino, CA.: Apple Computer.

Sandholtz, J. H., Ringstaff, C. & Dwyer, D. C. (1997) ***Teaching with technology: creating student-centred classrooms*****. New York: Teachers College Press.**

A study of student engagement based on self-report data from 32 elementary and secondary teachers whose students used technology in an ongoing basis. The study differs from previous research in that it is based upon reports from teachers rather than external observers, spans an extended period (six years) and includes new measures of student engagement.

Data was collected from 32 teachers at 5 sites representing a variety of grade levels and community types. Data includes bimonthly audiotapes on which teachers reflected about their experiences, weekly reports sent via electronic mail, and correspondence between sites. A grounded theory approach was used to analyse the data.

The study found that the introduction of computers resulted in increased student engagement which was sustained over time, but only under certain conditions, specifically:

- that computers were used a one tool among many, which encouraged appropriate use;
- that computers were used across the curriculum rather than being offered as a separate subject
- emphasis was placed on using software tool applications for generative activities rather than software tutorials and
- that differences in interest and ability must be provided for.

The maintenance of engagement challenges the belief that increased enthusiasm during initial exposure to technology results from a novelty effect. The researchers also found that teachers' beliefs about their role in the classroom were challenged by the introduction of technology, which surfaced through the dilemmas they faced and, in many cases, led them to reassess and change their role.

[*Begun in 1985, Apple Classrooms of Tomorrow (ACOT) is a research and development collaboration among public schools, universities, research agencies and Apple Computer, Inc. ACOT explores, develops and demonstrates the powerful uses of technologies in teaching and learning. In all ACOT endeavors, instruction and assessment are as integral to learning as technology. Supporting a constructivist approach to learning, technology is used as knowledge-building tools. As students collaborate, create media-rich compositions and use simulations and models, researchers investigate four aspects of learning: tasks, interactions, situations and tools. The research is formative. The findings guide ACOT staff and teachers as they refine their approach to learning, teaching and professional development. ACOT teachers and students often use the most advanced technologies available, including experimental technologies, to help us envision the future and improve the educational process.]

Software & Information Industry Association. (1999) 1999 Research report on the effectiveness of technology in schools: executive summary 6th edition [Available URL: http://www.spa.org/project/edu_pub/99effreport.htm Accessed: 30 April, 1999]

Abstract:
This report, commissioned by the Software & Information Industry Association (SIIA)* and conducted by an independent educational technology consulting firm, Interactive Educational Systems Design Inc. (IESD), summarizes educational technology research conducted from 1990 through 1998. It is based on 264 research reviews and reports on original research projects, from both published and unpublished sources. Of these 264 studies, 112 were published in professional journals and 44 were doctoral dissertations. The 264 studies were chosen from an original set of more than 2,000.

The research examined varies in methodology including:
- a technique for synthesizing and analyzing data from many different studies
- studies that compare the use of technology to traditional instructional methods different software designs or the use of technology under different learning environment conditions
- studies based on classroom observation and surveys of educators and students.

The report excluded studies which were weak in methodology and those which addressed topics not of concern in this report (e.g., critiques of typical research methods; research on the attitudes of student teachers; research on the design of the physical layout of technology-rich classrooms).

The report is divided into three sections:
- Effects of technology on student achievement
- Effects of technology on student self-concept and attitudes about learning
- Effects of technology on interactions involving educators and students in the learning environment

The conclusions of the report were as follows:

Technology is making a significant positive impact on education. The findings of greatest importance in these studies include:

General

- The specific student population, the software design, the educator's role, how the students are grouped, the preparedness of the educator and the level of student access to the technology influence the level of effectiveness of educational technology.
- Educators are an essential element in the effectiveness of technology.
- Software is effective because it allows individual learner traits to be taken into consideration when software is being designed and used.
- Effectiveness of educational technology depends on a match between the goals of instruction, characteristics of the learners, the design of the software and technology implementation decisions made by educators.
- Students of teachers with more than 10 hours of training significantly out-performed students of teachers with 5 or fewer training hours.

Effects on Student Achievement and Motivation/Self-concept

- Educational technology has demonstrated a significant positive effect on achievement. Positive effects have been found for all major subject areas, in preschool through higher education and for both regular education and special needs students. Evidence suggests that:
  1. Interactive video is especially effective when the skills and concepts to be learned have a visual component and when the software incorporates a research-based instructional design.
  2. Use of distance learning has been shown to be as effective or more effective than instruction that takes place locally.
  3. Use of online telecommunications for collaboration across classrooms in different geographic locations can improve academic skills.
- Educational technology has been found to have positive effects on student attitudes toward learning and on student self-concept.
- Students felt more successful in school, were more motivated to learn and had increased self-confidence and self-esteem when using computer-based instruction. The evidence for these effects is the strongest in the curriculum areas of language arts, mathematics and science and for telecommunication and video technologies.
- The teacher's role is of primary importance in creating an effective, technology-based learning environment, an environment that is characterized by careful planning and frequent interaction among students and the teacher.
- Students who are field-independent learners (i.e., learners who rely less on contextual clues in defining meaning) perform better than field-dependent learners with hypertext do.
- Teacher professional development and decisions about how computers are to be used in instruction may matter more than how often technology in used.
- Educational technology has significant positive effects on both achievement and student attitudes for special need populations.
- Speech recognition is an especially valuable compensatory tool for the learning disabled.
- Students trained in collaborative learning in small groups had higher self-esteem and student achievement.

- Expanding student responsibilities through a learner - as - multimedia - designer environment can positively impact student attitudes.
- To positively impact student achievement and student motivation/self-concept specific software design elements are highly desirable:
  1. Offering students some control over the amount, review and sequence of instruction can result in higher achievement and better student attitudes toward learning than having the software control all instructional decisions. However, low-achieving students and students with little prior content knowledge are likely to require more structure and instructional guidance than other students are.
  2. In tutorial and practice software, programs with feedback providing knowledge of correct responses were found to be superior to programs that require students to answer until they are correct. Furthermore, feedback that identifies why a response is wrong was found to be more effective than feedback that only identifies what was wrong.
  3. Software that includes embedded cognitive strategies provides students with a learning advantage. Helpful cognitive strategies include repetition and rehearsal of content, paraphrasing, outlining, cognitive mapping or diagramming, drawing analogies and inferences, generating illustrative examples, specific techniques for reading in the content areas and using pictorial information.
  4. Students can benefit academically from software with embedded conceptual change strategies - sequences of instruction that move students from their faulty preconceptions to a more accurate understanding of the concepts involved.
  5. Animation and video can enhance learning when the skills or concepts to be learned involve motion or action.
  6. Content-related graphics (both static and animated) and video can help improve student attitudes and motivation in mathematics and science.
  7. Students using hypermedia software can benefit from an interface that includes a graphical browser or navigation map that shows the links among the various screens of information.
  8. Foreign language and ESL students can benefit from presentation of video segments with captioning (i.e., subtitles in the target language).
  9. Recent research suggests further exploration and possible inclusion of the following software design characteristics:
     - Stating objectives
     - Multitiered scaffolding of instructional support
     - Requiring note taking
     - Story and fantasy contexts
     - Game contexts with content-related visual metaphors
     - Multiple window presentation options (overlapping vs. tiled windows)
     - Dynamic visualization of abstract concepts
     - Still graphics in vocabulary development
     - Advanced organizers in simulations

Effectiveness of Interactions Involving Educators and Students in the Learning Environment

- Specific characteristics of the learning environment help to maximize the benefits of educational technology:
  1. District-level involvement and the leadership of a school-level computer coordinator are key factors in developing a school environment conducive to effective use of technology.
  2. Educators are more effective after receiving extensive training in the integration of technology with the curriculum.
  3. Exemplary computer-using educators benefit from a social network of other computer-using educators at their school.
  4. Exemplary computer-using educators typically have smaller class sizes and more funds available for software acquisition.
  5. Educators should carefully plan, and actively participate in, learning activities that incorporate tool software. Before students use database software independently, they should be given search strategy training.
  6. Educators should offer students self-directed learning experiences and activities that encourage self-expression.
  7. Students benefit from personal interaction among class members.
- Courses for which computer-based networks were used increased student-student and student - teacher interaction, increased student-teacher interaction with lower-performing students, and did not decrease the traditional forms of communication used.
- Many students who seldom participated in face-to-face class discussions become more active participants online.
- University and inservice teacher training provides educators with greater comfort in using computers, an increase in the desire to use computers and an understanding of how to integrate software into the classroom curriculum.
- Introducing technology into the learning environment has been shown to make learning more student-centered, to encourage cooperative learning and to stimulate increased teacher/student interaction.
- Positive changes in the learning environment brought about by technology are more evolutionary than revolutionary. These changes occur over a period of years, as educators become more experienced with technology. Long-time computer-using teachers tend to make changes in the learning environment generally related to a constructivist teaching approach.
- Greater student cooperation, sharing and helping behaviors occurred when students used computer-based learning in which students compete against the computer rather than against each other.
- Small group collaboration on the computer is especially effective when students have received training in the collaborative process.

Tierney, R. J., Kieffer, R., Stowell, L., Desai, L. E. & Whalin, K. (1992) Computer acquisition: a longitudinal study of the influence of high computer access on students' thinking, learning, and interactions. ACOT* Report #16. Cupertino, CA.: Apple Computer.

Tierney, R. J. (1996) Redefining computer appropriation: a five-year study of ACOT students. In *Education and Technology: Reflections on Computing in Classrooms* (C. Fisher, D. C. Dwyer & K. Yocam, Eds). San Francisco: Jossey-Bass. pp. 169-183.

The study follows six students during four years of high school and documents the impact of unlimited access to technology (at school and home) upon their thinking, approach to learning and interactions with other.

The study was based on observations of and interviews with the students over a period of five years and differs from other research in that it is a *sustained* study investigating the *integration* of technology and focuses on *student perspectives* rather than traditional measures.

The researchers identified dramatic shifts in the way students used technology, specifically:

- shifts in the way students developed documents on the computer;
- shifts in how students represented knowledge through the use of graphical and dynamic elements and hypertext or multi-layered structures;
- shifts in the way students experimented accessing and thinking about topics;
- shifts in how students communicated their ideas to their teachers, classmates and friends, as well as themselves and;
- shifts in students' goals and view of themselves as learners and individuals.

[*Begun in 1985, Apple Classrooms of Tomorrow (ACOT) is a research and development collaboration among public schools, universities, research agencies and Apple Computer, Inc. ACOT explores, develops and demonstrates the powerful uses of technologies in teaching and learning. In all ACOT endeavors, instruction and assessment are as integral to learning as technology. Supporting a constructivist approach to learning, technology is used as knowledge-building tools. As students collaborate, create media-rich compositions and use simulations and models, researchers investigate four aspects of learning: tasks, interactions, situations and tools. The research is formative. The findings guide ACOT staff and teachers as they refine their approach to learning, teaching and professional development. ACOT teachers and students often use the most advanced technologies available, including experimental technologies, to help us envision the future and improve the educational process.]

Wiesenmayer, R. L. & Koul, R. (1998) Integrating Internet resources in the science classroom: Teachers' perspectives, *Journal of science educational and technology*, 7(3), 271-7.

This paper reports on a study of teachers who participated in the West Virginia K-12 RuralNet project - a year long Internet training course. Survey data was collected from 169 participants, of which ten also took part in semi-structured interviews.

The results indicate changes to teaching practice with teachers using the Internet to support collaborative activities and communication both within the class and beyond. Most teachers used information from the Internet as a supplement to a traditional textbook, with a small percentage having replaced a textbook altogether with online materials.

In many classrooms learning activities changes with more hands-on, project-based and investigative activities taking place. Many teachers, however, were frustrated by the logistical problems of the technology and the lack of equipment. For the RuralNet group of teachers the Internet also provided contact with other teachers and enabled them to share lesson plans and resources.

Williams, D. C. (1999) The effects of expert stories on sixth grade students' achievement and problem solving in hypermedia-supported authentic learning environments (HALE). *Proceedings of ED-MEDIA/ED-TELECOM 99 World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications*. (pp. 112-118). Charlottesville, VA: Association for the Advancement of Computing in Education.

This paper reports on a research study which examines the effects of expert stories on students' achievement and problem solving. Students (n=101) in two sixth grade science classes were randomly assigned to the treatment conditions in which the learning environment provided support in the form of expert stories or expert non-stories. Specifically, the learning environment consisted of a hypermedia-supported authentic learning environment (HALE) developed in the content area of astronomy. The learning goals of the HALE were for students to be able to:

- Plan and implement procedures for solving complex problems
- Identify relevant information needed in solving a complex problem
- Identify the characteristics of objects in our solar system
- Describe components that comprise probes used for astronomical research
- Rationalize the design of a probe in regards to it's intended mission
- Analyze data and draw conclusions from astronomical data

The *Stories* version has an expert tool containing short first person narratives (video) related by an expert. The *Non-stories* version provides the same content as the *Stories* version, except the expert relates factual information with no story elements.

To measure effect of the treatment, measures of knowledge recall and transfer were administered. Recall was measured with an instrument containing multiple choice and fill-in-the-blank items tested for content validity. The recall instrument was administered as a pretest, posttest, and retention measure.

The near transfer (i.e., the ability of students to apply their knowledge in solving problems similar to the one received in the treatment) measure and far transfer (i.e., the ability of students are able to apply their knowledge in solving problems that they have not previously encountered) measure were administered as posttests where students were given with problems and asked to provide: a hypothesis of a solution to the problem; a rationale for hypothesis which includes supporting information learned while using the environment; an indication of other information that would need to be gathered to support the answer: a description of which scientific tools could be used to gather information to test the hypothesis. For each measure, an overall score was developed from scores for five criteria: (a) Quality/plausibility of the hypothesis and supporting rationale, (b) Level of incorporation of details and facts in the essay, (c) Thoroughness of analysis of needed information to support answer, (d) Number of tools cited and the appropriate use of them, (e) overall originality of ideas, (f) overall quality of the essay.

On the measure of factual knowledge recall, no significant difference was found between the story and non-story conditions. However, when asked to solve near transfer and far transfer problems, students in the story treatment did significantly better than students in the non-story condition. This finding suggests that expert stories can scaffold student learning. In particular, it appears that expert stories may help students transfer learning to novel situations.