Technology and Classroom Practices: An International Study

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Abstract

This study examines the findings from 174 case studies of innovative pedagogical practices using technology from 28 participating countries. The study looks at how classrooms worldwide are using technology to change the practices of teachers and students. Within many of these classrooms, the use of technological tools and resources supports students as they search for information, design products, and publish results. Teachers create structure, provide advice, and monitor progress. Beyond these commonly exhibited practices, the study identifies specific patterns of classroom practice that are more likely to be associated with reports of certain desirable student outcomes. Examples are provided. (Keywords: computers, educational technology, classroom practice, educational innovation.)

Researchers (Bransford, Brown, & Cocking, 2000; Roschelle, Pea, Hoadley, Gordin, & Means, 2000) posit that a number of features of new technologies are consistent with principles of the science of learning and hold promise for improving education. They contend that new information and communications technologies (ICT) can bring exciting curricula based on real-world problems into the classroom, and provide scaffolds and tools to enhance learning. The interactivity of technologies is cited as a key feature that enables students to receive feedback on their performance, test and reflect on their ideas, and revise their understanding. Networked technology can enable teachers and students to build local and global communities that connect them with interested people and expand opportunities for learning.

However, Bransford, Brown, and Cocking (2000) caution that the positive impact of technology does not come automatically; much depends on how teachers use ICT in their classes. A national study in the U.S. (Wenglinski, 1998) actually found a *negative* relationship between the frequency of use of school computers and school achievement. Similar findings came from international data (Pelgrum & Plomp, 2002). On the other hand, Wenglinski found that *certain uses of technology* had a *positive* effect on achievement. In the fourth grade, for example, the use of computers for learning games was positively related to math achievement. In the eighth grade, the teacher's professional development in the use of ICT and its use to teach higher-order thinking skills were positively related to math achievement. More recently, analyses of U.S. data (NCES, 2001) show a positive relationship between science achievement and the use of computer learning games in the fourth grade, the use of simulations in the eighth grade, and the use of computers to collect, download, and analyze data in the twelfth grade.

Research in the classroom (Means & Olson, 1995; Means, Penuel, & Padilla, 2001; Sandholtz, Ringstaff, & Dwyer, 1997; Schofield & Davidson, 2002) documents that some teachers are beginning to use technology to change pedagogy and curriculum. For example, in many countries the use of educational technology is part of an instructional shift toward constructivist approaches to teaching and learning within a context of school improvement or reform (Pelgrum & Anderson, 1999). Instead of focusing solely on increasing the acquisition of facts related to specific subject areas, teams of students are engaged in solving complex, authentic problems that cross disciplinary boundaries. Instead of dispensing knowledge, teachers set up projects, arrange for access to appropriate resources, and create organizational structures and support that can help students succeed. These approaches move the concept of learning beyond the rote memorization of facts and procedures toward learning as a process of knowledge creation (Bransford & Cocking, 2000). Constructivism envisions a learning process in which students set their own goals, plan their learning activities, and monitor their current levels of mastery and understanding in preparation for lifelong learning. It moves concepts of school beyond the notion of a place where knowledge is imparted, to one of classrooms, organizations, and societies as knowledge-building communities (Brown & Campione, 1994; Scardamalia & Bereiter, 1994).

Research studies have also begun to document a more integrated curricular role for ICT (Means & Olson, 1995; Means, Penuel, & Padilla, 2001; Sandholtz, Ringstaff, & Dwyer, 1997; Schofield & Davidson, 2002). Increasingly, ICT is coming to be incorporated into various subjects in the curriculum and across subjects. Although many teachers see ICT as a resource—often assessed by standardized tests—to help them teach the standard curriculum (Law et al., 2000; Schofield & Davidson, 2002), other teachers are coming to see ICT as a way of changing what is taught and how it is assessed. These teachers are using ICT within the context of complex tasks, conducted within a multidisciplinary context and extended blocks of time, and with performance-based assessment (Means & Olsen, 1995). As a result, it is proposed (OECD, 2001) that students will learn the skills needed for the 21st century, such as the ability to handle information, solve problems, communicate, and collaborate.

How do these pedagogical innovations look in the classroom? How is technology influencing the curriculum as it is implemented in the classroom? Can these practices be sustained and transferred to other settings? What kinds of local and national resources and policies are needed to support these practices? These were the research questions addressed by the Second Information Technology in Education Study Module 2 (SITES M2). SITES M2 (www.sitesm2.org) was a project of the International Association for the Evaluation of Educational Achievement (IEA; www.iea.nl) that involved research teams from 28 countries in Europe, North America, Asia, Africa, and South America[1]. At the international level, the project was coordinated by an International Coordinating Committee (ICC) of six scien-

[1] Countries included Australia, Canada, Chile, Hong Kong SAR, Chinese Taipei, Czech Republic, Denmark, England, Finland, Germany, Israel, Italy, Japan, South Korea, Latvia,

tists from the United States, Canada, and The Netherlands and directed by the Center for Technology in Learning at SRI International. The study found interesting similarities and differences in how teachers around the world use technology to support instructional change. The analyses reported in this article address questions related to similarities and differences in patterns of teacher, student, and technology practices and outcomes. Although the complete analysis (Kozma, 2003) addresses a broader range of research questions, the focus of this article is on patterns of innovative classroom practices that are supported by technology. We address a subset of the larger research questions: What are the practices of teachers and students in technology-supported innovative classrooms? What are the roles of teachers and students in these practices? What roles does ICT play? What are the similarities and differences among these practices? Are patterns among practices associated with other factors, such as outcomes, at least as they are reported?

DESIGN OF THE STUDY

To select cases, the researchers who participated in the study decided to combine an international set of criteria with local concerns. According to these criteria, the cases in each country that were to be selected were those where:

- there were significant changes in teaching, learning, or curricular practices.
- technology played a significant role in supporting these changes.
- the changes resulted in positive outcomes for students and/or teachers.
- the changes could be sustained and transferred.
- the changes were innovative, as defined by a national panel.

Research teams in each of the 28 participating countries formed national panels to select the innovative practices to be included in the international study. The panels consisted of researchers, teachers, school administrators, and policy makers—more than 240 people altogether. The average size of the panel was 8 members, ranging from 5 (Italy) to 18 (U.S.).

The panels reviewed the criteria, made modifications to suit local concerns, and provided a local definition for "innovative practices." These modifications and definitions were reviewed by the ICC. In their definitions of innovative practices, national panels often referenced social or cultural considerations and/or policy statements relating to ICT or education reform. For example, Singapore tied the definition to their national Information Technology Master Plan, and said that to be innovative a case must show evidence of a shift towards active student-centered learning. Thailand, referencing its National Education Act, indicated that ICT needed to accelerate changes in the roles of teachers, students, school administrators, and parents in innovative ways. Drawing on a national policy of building an Information Society, Finland provided a definition in which classrooms needed to provide students with competencies to search for, organize, and analyze information, and to communicate and express their ideas in a variety of media forms. The classroom also should engage students in collaborative, project-based learning in which they work with others

Lithuania, Netherlands, Norway, Philippines, Portugal, Russian Federation, Singapore, Slovakia, South Africa, Spain (Catalonia), Thailand, USA.

on complex, extended, real-world-like problems. Some countries (Taiwan, Finland, Netherlands, Norway, and Singapore) tended to associate innovativeness strongly with what students learn (e.g., ICT skills, social competencies, interpersonal skills), and with the students' motivation and willingness to learn.

The panels used these criteria to review many early possibilities and more than 220 final nominations. These final nominees were also reviewed by the ICC. Based on initial data collection, the panels finally selected 174 cases that were submitted for the international study. In some instances those classrooms and teachers that were initially nominated but not included in the final group did not meet one of the criteria upon additional examination. In other cases they were not included because they were not available to participate in the research. The number of cases included in the final group ranged from 1 (Japan) to 12 (Germany) and averaged about 6 cases per country. It is important to keep in mind that these cases are in no way representative or "typical" of what is happening in countries around the world. Rather, the cases can be seen as representing what national panels saw as the best practices in their countries based on the international and local criteria.

The research teams in each country used standard instruments and protocols that were field tested in 17 of the countries and revised based on these tryouts. The data were collected from a variety of sources that included interviews of administrators, teachers, students, and parents; classroom observations; and the analysis of documents, such as teacher lesson plans and samples of student work. The data collection typically took two researchers approximately one week at each site. The technical reports submitted by the national research teams after their field work identified no significant deviations from the data collection protocols.

The national researchers then used a standard template to write up each case report. The case report guidelines recommended a procedure for sorting the data according to the research questions and for writing up the data as a 10-page narrative. The narrative was divided into a standard set of sections that included school background, ICT support structure in the school, national policies, teacher and student practices and outcomes, kinds of technology and the ways they were used, sustainability, and transfer.

The 174 cases were in turn analyzed by the international researcher team (Kozma, 2003). The analytic approach used a mixture of qualitative and quantitative approaches (Tashakkori & Teddlie, 1998). The analysis involved a two-step process, in which for the first step all the cases were read by the ICC and classified along a variety of variables related to the research questions. This coding was reviewed by the national research teams. Initial analyses were based on these codes to identify a subset of cases related to each research question that would be coded in more detail during a second analysis. The analyses reported in this article address questions related to similarities and differences in patterns of teacher, student, and technology practices, and outcomes. Although the complete analysis (Kozma, 2003) addresses a broader range of research questions, the focus of this article is on patterns of innovative classroom practices that are supported by technology.

TRENDS OF CLASSROOM PRACTICE

As a group, the cases were quite evenly divided among primary, lower secondary, and upper secondary grades, with about 35% of the cases at each level, as classified by the ICC. A large number of cases were in the sciences, with 25% in biological or life sciences, 14% in earth sciences, and 13% in physics. Another 21% were in mathematics. Language and literacy accounted for another large group, with 32% of the cases in mother tongue and 24% in foreign languages. A smaller group of cases were in the social sciences (14% in geography, 16% in history, and 13% in civics) or creative arts (20%). It is an interesting finding that only 21% of the cases involved computer education or informatics as a subject area and that only 8% were focused on vocational studies. This confirms that ICT has become integrated throughout the curriculum, at least in this set of innovative cases. Indeed, many of these ICT-based innovations involved multidisciplinary projects (28%) or multiple subject areas, with 37% of the reports involving several subject areas and 32% involving nearly all of the subject areas in the school. In only 29% of the cases was the innovation limited to a single subject area.

Nearly 90% of the cases said that teachers were engaged in advising and guiding their students' work as part of the innovation. A large number of cases also described more traditional practices such as creating structure (81%) and monitoring or assessing student performance (76%), although only 25% reported that the teacher engaged in lecturing as part of the innovation. Nearly 59% of the cases reported that teachers collaborated with other teachers as part of their innovation. But only 23% reported that teachers collaborated with people outside the class, such as professors, scientists, or business people. The reported impact on teachers was primarily the development of their ICT skills (63% of the cases reported this) and pedagogical skills (57% reported this). Another group of cases—35%—reported that teachers acquired collaborative skills as a result of the innovation.

According to the case reports, in 83% of the innovations students collaborated with each other, either in pairs or small groups. Students in a large majority of these innovations were actively engaged in constructivist activities, such as searching for information (74%), publishing or presenting the results of their work (66%), or designing or creating products (61%). Only 26% of the cases reported that students collaborated with people outside the classroom.

What kinds of technology did teachers and students use and what role did ICT play in supporting these innovations? A large majority of the innovations use productivity tools (78%), Web resources (71%), and e-mail (68%). Many—52%—used multimedia software. Some used Web design tools (34%). Very few used specialized educational software such as simulations and microcomputer-based laboratories (13%). In almost all of the cases—94%—computers were used in regular school settings such as the classroom, library, or computer laboratory. In few cases—28%—technology was used outside of the school. Software packages were used to create products or presentations (80%), Web browsers or CD-ROMs were used to search for information (77%), and e-mail was used to support communication (55%). In far fewer cases, teachers used ICT to plan or organize instruction (26%) or to monitor or assess student work (22%). In a small number of cases ICT was used to support student collaboration (17%), or simulations or modeling software packages were used for research or experimentation (13%).

The stated impact of the innovation on students was quite broad. The largest number of cases claimed that students acquired ICT skills as a result of the innovation (75%). A large majority of cases claimed students developed positive attitudes toward learning or school (68%), acquired new subject matter knowledge (63%), or acquired collaborative skills (63%). But fewer than half of the cases reported that students acquired new study skills (38%), communication skills (40%), information handling skills (29%), or problem solving skills (19%) associated with learning for the 21st century (OECD, 2001). It should be noted, however, that statements made about the impact of the innovation on students and teachers were based on existing evidence, often the claims of teachers, principals, or students. Our research teams did not have the resources to independently verify these claims, although the same claim from multiple sources increased our confidence in its validity. Nonetheless, outcome statements should be viewed with some caution until future research investigates these relationships more deeply.

PATTERNS OF CLASSROOM PRACTICE

Beyond the frequency of various classroom practices, the success of innovations may depend on the ways these practices are used together. In addition to looking at the overall tendencies of practices across cases, a cluster analysis was performed to examine how classroom practices were used together within cases (k-means clustering; SAS FASTCLUS procedure). Cluster analysis is an interpretive quantitative procedure: there is no single solution to the analysis and the outcome selected from the various ones generated is the one that is most satisfying, relative to the goals of the analysis (SAS Institute, 1990). This quantitative approach is particularly compatible with the qualitative nature of this study.

An eight-solution analysis was used in this study. As part of the analysis, the procedure forces each of the cases into membership in one cluster or another, based on its closeness to the means of other group members on the variables used in the analysis. Seven meaningful patterns of classroom practice were identified. These were defined by the variables for which their mean scores were highest or above the overall means. An eighth cluster did not score high on any of the variables and was left undefined. The seven defined clusters are briefly described in Table 1.

Several practices were common to a number of clusters. For example, students were likely to search for information in all of clusters except the Tutorial Cluster. The practice was most likely to happen in the cases assigned to the Information Management Cluster. Indeed, *all* of the cases in the Information Management Cluster reported that students were involved in searching for information. However, clusters were formed not around one particular practice but around a pattern of interlocking practices.

Table 1: Descriptions of Practices for Different Clusters

Descriptions in bold were the highest means among clusters; other descriptions were above average relative to the overall mean.

TEACHER PRACTICES

Tool Use (N=14)

N/A.

Student Collaborative Research (N=14)

Teachers in this cluster were most likely to give lectures and provide structure for students. They provided advice and monitored student progress during student activities. They often designed materials.

Information Management (N=22)

Teachers in this group most often designed materials and created structure for students. They often provided students with advice and monitored their progress. They often collaborated with colleagues.

Teacher Collaboration (N=19)

Teachers in this cluster were most likely to collaborate with colleagues, students, and outside actors. They also designed materials, created structure for students, provided them with advice, and monitored their progress.

Outside Communication (N=27)

Teachers often created structure, advised students, and monitored their progress. They also collaborated with colleagues.

Product Creation (N=35)

All the teachers in this cluster created structure and advised students.

Tutorial (N=12)

Teachers often designed materials, frequently in collaboration with colleagues.

Table continued on page 8

For example, the Information Management Cluster was a particularly rich pattern of practices, as seen in Table 1. Among those common in this cluster was the practice of teachers creating structure for students and preparing instructional materials—teachers in *all* of the cases in this cluster created structure (compared to 80% of the cases overall) and teachers designed materials in 91% of the cases in this cluster (compared to only 58% overall). In *all* of the cases, ICT was used by teachers and/or students to plan and organize instruction (compared to 26% overall) and to create products or presentations (80% overall). ICT was used to monitor or assess students in 86% of the cases in this cluster. This was done in only 22% of the cases overall. In 23% of the cases ICT course management tools were used, more often in any other cluster; only 6% of the total cases did so. Productivity tools were used in *all* cases in this cluster, as they were in several other clusters, including all of the cases in the ICT Tools

Table 1, con't

STUDENT PRACTICES

Tool Use (N=14)

Students often collaborated with each other to search for information and create products.

Student Collaborative Research (N=14)

Students in this cluster were most likely to collaborate with other students to conduct research and analyze data They also searched for information and solved problems.

Information Management (N=22)

Students in this cluster were most likely to search for information, solve problems, publish results, and assess their own work and that of others. They also collaborated with other students to conduct research and create products.

Teacher Collaboration (N=19)

Students in this group were most likely to pick their own tasks. They also collaborated with each other and others outside the class to search for information, create products, and publish results.

Outside Communication (N=27)

Students in this cluster were most likely to collaborate with others outside the class. They also collaborated with other students to conduct research, search for information, create products, and publish results.

Product Creation (N=35)

Students in this cluster were most likely to create products. They also collaborated with each other to search for information and publish results.

Tutorial (N=12)

Students in this group were most likely to engage in drill and practice.

Table continued on page 9

Cluster. Web resources were also used in 95% of the cases. Students searched for information in *all* the cases, compared to 74% overall. They frequently published or presented results (95% compared to 66% overall), solved problems (77% versus 33% overall) and assessed their own and/or each others' work (54% versus 30% overall).

An example case might illustrate some of the characteristics of this cluster. For example, an upper secondary school in the U.S., called "Future High School," was assigned to the Information Management Cluster. The school was redesigned from the ground up around technology and project-based learning, and was organized as a high-tech start-up business in which students were given real-world projects consisting of complex tasks with long-range due dates for which they have individual and shared responsibility. Students used computers on a daily basis for everything from research on the Internet to a multimedia integrated design project that combined interdisciplinary content from social

Table 1, con't

ICT USE

Tool Use (N=14)

Students and teachers in this group were most likely to use productivity tools and e-mail. They also used multimedia tools and Web resources. They used technology to create products, search for information, and communicate.

Student Collaborative Research (N=14)

Students and teachers in this group were most likely to use Web design tools, multimedia, e-mail, laptops, and local area networks. They were most likely to use technology to simulate research and collaborate. They also used Web resources and productivity tools and used technology to communicate, search for information, and create products.

Information Management (N=22)

Teachers in this group were most likely to use course management tools and to use technology to plan instruction and monitor student progress. Teachers and students were most likely to use Web resources to search for information and productivity tools to create products. They also used multimedia, local area networks, and e-mail to communicate.

Teacher Collaboration (N=19)

Teachers and students in this group were most likely to use technology to create products and to use simulations. They also used productivity tools, multimedia, and e-mail. They used the Internet to search for information and communicate with others.

Outside Communication (N=27)

Students and teachers in this group were most likely to use collaborative environments and were among the most frequent e-mail users. They most often used technology to communicate. They used Web resources to search for information and they used productivity tools.

Product Creation (N=35)

Students and teachers in this group were among those who most often used technology to create products. They also used Web resources to search for information and used productivity and multimedia tools.

Tutorial (N=12)

All the students in this group used tutorial packages.

Table continued on page 10

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studies, math, science, economics, government, and literature. Students completed an online portfolio that was assessed by a panel of staff and community members. With 250 computers in the school, students used *Microsoft Office*, *Filemaker Pro*, *Lotus Notes*, *Adobe PageMaker*, and *Photoshop* to create business cards, stamps, posters, letterheads, Web pages, and other integrated multimedia products.

Table 1, con't

CLAIMED OUTCOMES

Tool Use (N=14)

N/A.

Student Collaborative Research (N=14)

Students in this cluster were most likely to acquire new ICT, problem-solving, and collaboration skills. Teachers acquired new pedagogical skills. The curriculum and class day was more likely to be reorganized

Information Management (N=22)

Students were more likely to acquire ICT skills, communication and collaboration skills, and information handling and problem solving skills. Teachers acquired new pedagogical skills. The curriculum was more often reorganized.

Teacher Collaboration (N=19)

Teachers acquired new collaborative skills.

Outside Communication (N=27)

N/A.

Product Creation (N=35)

N/A.

Tutorial (N=12)

N/A.

Another complex pattern of practices was the Student Collaborative Research Cluster. As the name implies, cases in this cluster are characterized by a pattern of student activities that includes collaboration with other students in the class (in *all* of the cases, compared to 83% overall), typically doing research (86% versus 39% overall) and occasionally conducting data analysis (36% versus 22% overall), more so than cases in any other cluster. In *all* cases teachers supported their students by giving advice, structuring their activities, and monitoring student progress (compared to 90%, 80%, and 76% overall, respectively). Frequently—71% of the cases in this cluster versus 25% overall—teachers lectured or otherwise provided content. In *all* of the cases, students used local area networks and e-mail and they frequently used multimedia (86% versus 52%) and occasionally Web design tools (50% versus 34%) and laptops (43% versus 16%), more so than cases in any other cluster. ICT practices occasionally included the use of simulations or modeling to support research and the support of students' collaboration—50% of the cases for both practices versus 17% and 13% overall, respectively.

A case that illustrates the practices in the Student Collaborative Research Cluster includes an Australian primary school in which students participated in research activities associated with the *Jason Project*—a series of real-life, Internet-based science explorations designed for students (www.jasonproject.org).

The students followed Jason researchers as they explored the geology and biology of a group of isolated islands in Hawaii, traced the migration paths of the diverse peoples who settled these islands, and explored the cultural tapestry of modern Hawaii. Students in this school were presented with two research questions and required to select one of them as their research topic. They had access to the school's computers and various software tools for their research. Working in teams, students used *Inspiration*, an idea organizing tool, in their initial research planning and *PowerPoint* to construct the final presentations of their completed research. Digital still and video cameras were frequently used to capture source material for the multimedia productions. Students also used *iMacs* to produce movies for their presentations.

The Teacher Collaboration Cluster is characterized most by teachers' collaboration with students (in *all* cases, compared to 24% of the cases overall) and with their colleagues (95% versus 59%). In 42% of the cases in this cluster, teachers collaborated with outside people, such as researchers, professors, and business people, more so than in cases in other clusters. This compares with 23% of the overall cases. Technology was used to create products in *all* of the cases in this cluster. In 89% of the cases, students picked their own tasks, compared to 40% overall. In a large majority of cases, students searched for information (89%), published results (79%), and created products (74%), compared to 74%, 66%, and 61% overall respectively. Students in the cases in this cluster more often collaborated with each other (95% versus 83% overall) and with others outside the class (53% versus 26% overall).

An example of a case in the Teacher Collaboration Cluster is the "Hypertext Development Project," which took place in an upper secondary school in the Slovak Republic. This innovation was started by two informatics teachers who created hypertext educational materials for programming courses and began to develop these educational materials together with students. Students learned how to create hypertexts, using HTML code, scripting languages, and text, graphic and sound editors. Then the teams or individual students worked with teachers over a 3–5 month period to develop educational hypertext materials in areas such as mathematics, physics, the Slovak language, and history. Topics were selected in collaboration between teachers and students. The finished projects were presented on the school Web page for use by other students. During the project, subject matter and informatics teachers acted as consultants, managers, and supervisors of the students; at the same time they also acquired new learning. The resources of this school are modest, with 30 computers in three classrooms—24 are connected to the Internet, seven are multimedia computers.

External collaboration was a characteristic of the cases in the Outside Communication Cluster. Cases in this cluster are characterized by the use of e-mail, the Internet, conferencing software, or listservs. Collaboration software environments were used in 33% of the cases versus 9% overall. In 96% of the cases, e-mail or other communication tools were used to support communication. In a majority of the cases, students collaborated with actors outside of their classroom (56% versus 26% overall), such as students and teachers in other schools, sometimes in other countries.

An example of this case is a set of primary schools in Catalonia, Spain. This case involved collaboration among teachers in five primary schools in a rural district. Teachers from these schools got together under the leadership of one of their school principals and created a project called *ARRELS* ("Roots"), which engaged students in the collection of information about their local villages and the posting of that information on the Web. There were 16 computers and multimedia peripherals distributed among the five schools—between two and four to a school. Teams of students in each school worked on parallel research projects concerning their villages: history, monuments, village square, etc. They took digital photos, interviewed their grandparents, and shared their experiences with students in the other schools. They used word processing, e-mail, and digital photography to communicate with each other and to publish their reports on the Web in the Catalan language. Some of the Catalan songs and folk tales recorded from their grandparents were quite old and in danger of being lost to the culture. Teachers moved from group to group, helping students solve problems and reason out solutions.

The remaining three patterns in Table 1 were fairly simple in structure. For example, the Tutorial Cluster was characterized by a pattern of practices in which teachers (often working in groups) designed tutorial materials, which students used for drill and practice. In the Tool Use Cluster there were no distinctive teacher practices, but students worked together using a variety of productivity and multimedia tools to search for information and create products. Similarly, the Product Creation Cluster involved students in using a variety of productivity tools, Web, and multimedia resources to create products, while teachers created structure and guided students.

PATTERNS OF PRACTICE AND OUTCOMES

Beyond the clustering of classroom practices, certain patterns were more likely to be associated with desirable teacher and student outcomes. The relationship was examined between cluster membership and other variables not included in the cluster analysis, specifically a range of student and teacher outcomes, as reported in the case studies (See Table 1). Cases in the Information Management Cluster and the Student Collaborative Research Cluster were more likely to be associated with reported outcomes related to teacher and student outcomes than cases in other clusters. As for teacher outcomes, 85.7% of the cases assigned to the Collaborative Research Cluster and 72.7% of those assigned to the Information Management Cluster reported that teachers learned new pedagogical skills, as compared to 56.5% of the cases overall. Among student outcomes, cases assigned to the Student Collaborative Research Cluster and the Information Management Cluster were more likely to report acquisition of ICT skills (100% and 95.5% respectively), problem solving skills (35.7% and 45.5% respectively), and collaboration skills (78.6% and 90.7% respectively) compared to cases overall (where 75.3% acquired ICT skills, 18.2% acquired problem solving skills, and 63.0% acquired collaboration skills). In addition, cases in the Information Management Cluster were more likely to be associated with student acquisition of communication skills (72.7% of the cases in this cluster versus 39.4% overall) and information handling skills

(50.0% versus 28.2% overall). Cases in the Teacher Collaboration Cluster were more likely to be associated with teacher acquisition of collaboration skills (63.2%) than cases overall (34.7%).

CONCLUSIONS

The results of SITES M2 and its cases demonstrate that technology-supported innovative classroom practices in many countries around the world have many qualities in common. Based on these selected cases, teachers in many countries are beginning to use ICT to help change classroom teaching and learning, and are integrating technology into the curriculum. Students are working together in teams and using computer tools and resources to search for information, publish results, and create products. Teachers are using ICT to change their role from that of primary source of information to one who provides students with structure and advice, monitors their progress, and assesses their accomplishments. These case studies add detail to earlier comparative studies (Pelgrum & Anderson, 1999) and provide an international character to findings from classroom studies in the U.S. (Means & Olson, 1995; Means, Penuel, & Padilla, 2001; Sandholtz, Ringstaff, & Dwyer, 1997; Schofield & Davidson, 2002). Although the number of teachers around the world who are integrating technology into their classrooms may still be small, these cases provide a basic model for how teachers can start to use computers in their teaching.

Beyond this basic set of practices, the results of this study indicate that other classroom practices are more likely to be associated with certain teacher and student outcomes, at least as they are reported in our case studies. It seems that tool use and tutorials alone may not have as great an impact on student learning as technology-based research projects and technology used to manage information, at least according to self reports. Additional outcome studies are needed in the area of classroom ICT use. Specifically, studies are needed that directly assess the impact of ICT on student learning, especially those skills such as information handling, problem solving, communication, and collaboration that are considered important for the 21st century. However, the outcomes reported in our cases suggest that when teachers go beyond these basic practices and use technology to also plan and prepare instruction and collaborate with outside actors, and when students also use technology to conduct research projects, analyze data, solve problems, design products, and assess their own work, students are more likely to develop new ICT, problem solving, information management, collaboration, and communication skills.

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References

Brown, A. & Campione, J. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229–270).

Bransford, J., Brown, A., & Cocking, R. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academic Press.

Kozma, R. (Ed.) (2003). *Technology, innovation, and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education.

Law, N., Yuen, H., Ki, W., Li, S., Lee, Y. & Chow, Y. (2000). *Changing classrooms: A study of good practices in using ICT in Hong Kong Schools*. Hong Kong: Centre for Information Technology in School and Teacher Education, University of Hong Kong.

Means, B., & Olson, K. (1995). *Technology's role in education reform: Findings from a national study of innovating schools*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Means, B. Penuel, W., Padilla, C. (2001). *The connected school: Technology and learning in high school*. San Francisco: Jossey-Bass.

National Center for Educational Statistics [NCES] (2001). *The nation's report card: Science 2000*. Washington, DC: National Center for Educational Statistics.

Organization for Economic Co-operation and Development [OECD] (2001b). *Learning to change: ICT in schools*. Paris: OECD.

Pelgrum, W. & Anderson, R. (1999). *ICT and the emerging paradigm for life long learning: a worldwide educational assessment of infrastructure, goals, and practices*. Amsterdam: IEA.

Pelgrum, W. & Plomp, T. (2002). Indicators of ICT in mathematics: Status and covariation with achievement measures. In A.E. Beaton & D.F. Robitaille (Eds), *Secondary analysis of the TIMSS data*. Dordrecht, The Netherlands: Kluwer Academic Press.

Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2000). *Future of Children*, *10*(2), 76–101.

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

Scardamalia, M. & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences*, *3*(3), 265–384.

Schofield, J., & Davidson, A. (2002). *Bringing the Internet to school: Lessons from an urban district*. San Francisco: Jossey-Bass.

SAS Institute (1990) *SAS/STAT user's guide*. Cary, NC: SAS Institute Inc.

Tashakkori, A. & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Thousand Oaks, CA: Sage.

Wenglinski, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: ETS.