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Sustainability, Scalability and Transferability of ICT-based Pedagogical Innovations in Israeli Schools

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ABSTRACT *For more than two decades the Israeli Ministry of Education and various educational agents have systematically attempted to facilitate the nationwide implementation of information and communication technology (ICT) in schools. Two significant phases of this effort can be identified: the first, in 1993–1998, focused mainly on building the technological infrastructure within schools. The second stage (1998–2003) deals primarily with curricular and staff training aspects. This paper presents data collected between the years 1999–2000 for the Organization for Economic Cooperation and Development/Centre for Educational Research and Innovation international research of ICT and organizational innovation in five Israeli schools that have widely implemented ICT in a way that has provoked substantial organizational change. We analyze the data collected from two perspectives: (a) using an innovation analysis framework for characterizing ICT-based educational innovations, examining the levels of the innovations (in a sequence progression from initial assimilation of the innovation to a substantial organizational transformation), in four different domains of the schools' functioning (time and space configurations, students' roles, teachers' roles, curricular issues); (b) addressing key issues related to the prospects for sustainability, transferability and scalability of the innovations.*

During the last decades, ICT (information and communication technology) has become a vital component in schools and schooling (Pelgrum &

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Anderson, 1999). ICT implementation has affected schools' functioning at multiple levels: new configurations of learning spaces and timetables have been created; innovative teaching methods have been incorporated; autonomous and active learning processes using technology have been adopted; teachers' traditional roles have been expanded to include personal and group tutoring and guidance functions; and new ICT-based curricular solutions have been generated (Venezky & Davis, 2002).

Still, there are no conclusive answers as to the nature and extent of the impact of ICT in schools. A recent international study conducted by the International Association for the Evaluation of Educational Achievement established that ICT is regarded as a tool for promoting traditional as well as innovative pedagogy (Pelgrum & Anderson, 1999). Another study examined 436 educational web sites and found that in general, the current state of the educational implementation of the Internet represents mainly the phrase 'one step ahead for technology, two steps back for pedagogy' (Mioduser *et al*., 2000). However, Venezky & Davis (2002) found that 'ICT favors the prepared organization' and serves as a powerful lever for change when new directions are carefully planned, staff and support systems are prepared, and resources for implementation and maintenance are provided.

In this paper we address the relationship between innovative pedagogical practices using ICT and prospects of the sustainability, scalability and transferability of these innovative practices, as found in five Israeli schools which have implemented ICT successfully.

We begin this paper with a review of the state of ICT in the Israeli school system. Subsequently, we describe the levels and domains of innovations using ICT. In the third section we take up the matter of sustainability, scalability and transferability, and its relationship to the diffusion of educational innovation.

Background

ICT in Israel

ICT implementation in Israeli schools goes back as far as the 1970s. By 1993, the Ministry of Education released an operative proposal for the computerization of the education system known as the 'Five-year National Computerization Program'. Its main goals were to supply infrastructure according to defined standards (hardware configurations and software requirements), to provide pre-service and in-service training to most teachers in the system, and to foster equity of ICT access for students. Between 1994 and 2001 about 75,000 computers were allocated to approximately 2500 schools.

In 1999, the ratio of computers per student in primary schools was 1:18, and this ratio was 1:14 for lower and upper secondary schools.

Accessibility to the Internet is still limited: only 35% in primary schools, 53% and 72% in lower and upper secondary schools respectively (Nachmias *et al*., 2003).

Currently, the second phase of the computerization program (for the years 2000–2005) is being implemented. Built on the conclusions of the previous phase, the new plan focuses on students' acquisition of learning and knowledge-handling skills, ICT-related ethical issues, expanding the depth and scope of teacher training programs, incorporating network technologies into teaching and learning, and encouraging experimentation, research and evaluation by schools and research institutions.

Technology has come to play a substantial role in many Israeli schools, contributing to changes in the curriculum as well as in teacher–student encounters (Nachmias *et al*., 2000). Innovative pedagogical practices using technology are, in fact, emerging in many of our schools, resulting in changes in teaching and learning processes and outcomes, as well as providing students with lifelong learning skills, competencies and the ICT literacy needed in the information society; some changes were in fact impossible to accomplish without ICT.

The Study

The work reported here is the result of our participation in the international study sponsored by the Organization for Economic Cooperation and Development (OECD), focusing on innovations using ICT at the school system level (OECD/CERI [Centre for Educational Research and Innovation], 2000). We present data collected between 2000–2001 in five Israeli schools that have widely implemented ICT, which involved substantial organizational and pedagogical change. The research issue we intended to clarify through a description of an analysis of the levels and domains of innovation observed in the schools was to find out how ICT related to innovations in these schools and to what extent their innovative practices were scalable and sustainable.

School Selection Procedure

On the basis of information collected regarding about 100 schools, and the application of selection criteria, the study's steering committee proposed the final list of candidates for the case studies.

Selection criteria stated that an appropriate candidate is a school innovation:

> that shows evidence of significant changes in teachers' and students' roles, curriculum goals, assessment practices, and/or the educational materials or infrastructure;

in which technology plays a significant role in curricular implementation;
that shows measurable evidence of positive student outcomes;
that is sustainable (at least 2–3 years from its beginning) and potentially transferable and scalable;
that is innovative, as defined by the members of the steering committee (e.g. taking into consideration additional issues such as dealing with equity or addressing students' special needs).

The population consisted of five schools in Israel, including two elementary schools, one junior high school, one three-year high school and one six-year high school (the schools are labeled IL01–IL05, IL standing for Israel):

IL01—Website Story: four-year high school (grades 9–12), 1250 students, 120 teachers, average-high socioeconomic status (SES), 120 computers.

The school's innovative project consists of the construction of a school Internet site, a three-year project which is currently ending its second year. The aim of the project is to build a representative as well as an active Internet site which will serve different populations, both within the school boundaries and outside them. The site contains relevant information for students and teachers, databases in the various school subjects, and numerous interactive learning activities. It is based on the usage of innovative technology as well as innovative teaching paradigms.

IL02—ICT Saturated Learning Environment: primary school (K-6), 1000 students, 55 teachers, high-average SES, 200 computers.

The school was planned and built as a 'school of the future', and, according to an educational concept that views ICT as a means for empowering and redefining the relationship between students and knowledge, for facilitating learning skills acquisition, and improving academic achievement. Computers are implemented in most subjects, enabling a variety of learning activities such as: animation in arts classes, a class database, a class questionnaire edited in *Microsoft Word* and a web quest. Students engage in ICT for one hour a day on average, in groups, pairs and individually. Computer-based alternative assessment methods enhance students' involvement (URL: www.cramim.rishon.k12.il).

IL03—Computer Trustees: lower secondary school (grades 7–9), 630 students, 53 teachers, high-average SES, 70 computers.

In this innovation human resources are viewed as a main factor for supporting the assimilation of ICT in everyday life and in school. Students with the appropriate background were identified and offered adequate training, enabling them to participate in the ongoing maintenance of the computers within the school and in the construction and maintenance of the school web site. These students also participate in teacher training courses,

each student serving as a tutor to a teacher. This tutoring operates also during school hours, with students helping teachers in using the ICT lab. They were also participating in community projects such as training senior citizens in how to use ICT (URL: www.atarnet.net/il/barlev, in Hebrew).

IL04—'Beehive' Communication Projects: religious primary school (grades 1–6), 620 students, 50 teachers, mixed SES, 60 computers.

This school is a saturated web-based learning environment, participating in no less than 10 virtual communities involved in learning in different areas. The Beehive project is operated by the Center of Educational Technology, a non-profit organization fostering the use of technology in schools and developing, among other products, web-based learning environments. The emphasis in this school is on virtual communities dealing with language skills: 'Reading and Writing', 'Reading and Writing Stories' and 'About Three Things'.

IL05—Man and Surrounding Website: secondary school (grades 7–12), mixed SES, regional school, 380 students, 25 teachers, 25 computers.

The school web site was built as part of the educational curriculum. It contains descriptions and research dealing with physical and human aspects of the area, mainly a salt flat. The students built a database comprising materials related to the earth sciences, biology, computer sciences and the arts. The web site is also used as an interactive interface for online assignments. Since last year, there has been a connection between the school and a couple of schools in Jordan. The web site serves as a virtual meeting place for joint activities between the schools, and its development is due to a joint effort of students from both countries and from the USA (URL: shahroot.kfar-olami.org.il).

Data Collection Tools

Eleven data collection tools were designed by the international research group, translated into the Hebrew language and adapted locally: principal questionnaire; principal interview; computer-coordinator questionnaire; computer-coordinator interview; focus-group interview of teachers involved in the innovation, and teachers not involved in the innovation; focus-group interview of students involved in the innovation; focus-group interview of parents familiar with the innovation; observations; teacher ICT survey, and learning products analysis.

Data Collection Process

All data were collected at the five school sites between December 2000 and June 2001 by a team of nine researchers. Small teams of 2–3 researchers visited the schools 3–5 times, spending altogether about 60 accumulated

hours per school. A typical interview lasted about an hour and a half, and was held by one researcher. Classroom observations typically lasted 45 minutes and were held in pairs. All interviews were recorded and all observations were transcribed. All data were thereafter transcribed into digital files and uploaded to the Israeli research web site (http://muse.tau.ac.il/ict).

Data Analysis

Levels and domains of innovation. An innovations analysis schema was developed (for a detailed description see Mioduser *et al*., 2003; Tubin *et al*., 2003). The horizontal axis represents levels of innovation, ranging from preliminary alterations in school routine due to the initial assimilation of ICT, to far-reaching transformations of pedagogical practices and learning processes. Three main levels were defined. In the first level—*assimilation*—specific pedagogical situations change qualitatively, but the school curriculum as a whole (e.g. content and goals), the instructional means (e.g. textbooks), the learning environment (e.g. classrooms, labs), and the learning organization (e.g. timetable) remain unchanged. In the second level—*transition*—ICT supports the integration, within the school's everyday functioning, of new contents, didactic solutions, and organizational solutions side by side with the traditional ones. In the third level—*transformation*—substantive changes take place in the school system as a whole. Traditional processes still exist, but the school's identity is mainly defined by the rationale and goals of new approaches and lines of operation; student and teacher roles are enriched with new dimensions; new curricular contents are introduced; new teaching methods are developed and implemented; and for particular activities the traditional time and space configuration is transformed.

The vertical axis details domains of innovation, focusing on four main constituents of the school's milieu: time/space configurations, students, teachers and the curriculum. Two independent evaluators analyzed each case study's data using the above schema. Each evaluator scored each school in each domain on a five-point scale: 1—basic assimilation level; 2—beginning of the transition; 3—transition level; 4—beginning of the transformation level and 5—full transformation level (it should be noted that the analysis unit in this study concentrates on specific innovative pedagogical practices using ICT within schools, and not on the school as a whole). The evaluation resulted in 45 school-level-locations (SLL), for nine sub-domains in five schools. Out of the 45 SLLs, matching judgment was reached for 37 (83%) in the first evaluation round. The remaining 17% were discussed and elucidated by the evaluators and other members of the research team until full agreement was reached. Additional clarifications can be found in Tubin *et al*. (2003).

Scalability, sustainability & transferability. The operationalization of the three processes was defined on a five-point scale. Two independent evaluators analyzed each case study's data using the above schema. In 13 out of 15 evaluation units a matching judgment was reached. The remaining two were discussed until full agreement was achieved.

Results

Levels of Innovation in Schools

The five schools presented in this study were considered successful examples of using ICT for pedagogical practices in an innovative way. Yet, the question remains whether and how this innovation is reflected in some or all domains of the particular school's activities. Data indicate that most schools, in most of the innovation domains, are at the transition levels (3–4) (27 out of the 45 SLLs—60%), reaching the transformation level only in some domains (8 SLLs—17%). Taking into account that the five schools were selected as models for innovation, this distribution shows a different pattern than expected. The following sections examine specific findings.

Time and Space Configurations

Physical space. In general, the classroom walls remained intact. Four out of the five schools were at the assimilation and transition levels, with their computers located in public spaces (e.g. computer room, laboratory). In the remaining school (IL02), located at the transformation level, the building was designed from scratch in an innovative and technology-oriented approach, integrating extensive ICT facilities in all learning spaces.

Digital space. Most of the schools are located at the transition level and beyond. For example, several schools have developed web sites serving as online newsboards (IL03), as portals to dynamic learning centers (IL01), or as virtual gateways to web sites all over the world (IL05).

Time configuration. At the assimilation level ICT is incorporated in activities within the structured schedule and timetable, as in IL04, which operates 10 web-based learning environments embedded in the regular timetable. At the transition level, periods are organized in time blocks within which the students are free to use the computer for their needs (e.g. students acting as computer trustees are allowed to skip regular lessons to complete their computer assignments). Two schools located at the highest levels of innovation showed a fairly flexible organization of time. For example, high school IL05 allows its students to use ICT throughout the school day, as part of their work duties.

Student and Teacher Roles

Most of the innovative practices (four out of five) caused a significant change in the role of the students, who became web site constructors, teachers' assistants in ICT-related matters or ICT project managers. All schools were located at the transition level and beyond, showing interesting changes in teachers' roles. For example, in high school IL01, teams of teachers and students (grades 10–12) work together in developing web sites in about 20 subjects, which serve the ongoing teaching and learning in the school. This interaction eventually makes the teacher more familiar with the technology and the students more knowledgeable about the disciplines.

In three out of five innovative practices the relationships among teachers are at the transition level and below, showing only limited teamwork and collaboration. In the transformational level, essential teamwork takes place, as in the case of IL02, where teachers actually have become dependent on each other for curriculum development and instruction.

Curriculum Change

ICT use affects curricular contents in diverse ways. In three schools in which the innovative practices were at the transition level or below, ICT supported only an expansion of the traditional subjects. At the transformation level, schools used ICT for dealing with new subjects. For example, students in high school IL05 (grades 10–12) developed a comprehensive web site about the salt flat located near the school, and collaborated with Jordanian students working on contents and issues related to the shared natural phenomenon.

Three of the innovations observed pertained to the transition level, e.g. the use of digital worksheets stored in web sites to practice earlier studied topics, or searching the Internet for information to be used in class. At the transformation level the learning activities are qualitatively upgraded by the use of ICT.

In school innovations at the assimilation level, ICT is implemented in a traditional fashion. Innovations located at the transition (two schools) and transformation (two schools) levels included the use of novel assessment procedures such as polls, web site design contest, or digital portfolios.

Sustainability, Transferability and Scalability

This section presents an examination of the prospects of each innovation in terms of the issues of sustainability, transferability and scalability (STS). Since the research was designed as a group of case studies, estimation is based on the application of analytic criteria rather than on actual

longitudinal data. Results indicate that some innovations have more chances to be replicated and sustained (e.g. IL01, IL04) than others (e.g. IL02). Nevertheless, it seems that these cases are highly valuable as models to learn from rather than as models to be reproduced.

A case of interest is IL02—the 'school of the future'. Very special conditions were needed to plan, develop and implement the whole set of innovative ideas that constitutes this school. These conditions included special investments from the Ministry of Education, the district and the municipality, and the continuous support (for seven years now) of an academic adviser from Tel Aviv University. The school's daily functioning is supported by a solid infrastructure (e.g. servers, hundreds of computers, access to the Internet, ongoing maintenance) and human resources (e.g. a knowledge engineer who is part of the school staff). The uniqueness of the school, its outstanding outcomes and long-term experience have resulted so far in the consolidation of sustainability mechanisms, but at the same time it is clear that the conditions required are a serious obstacle for the transfer or scalability of the model. Notwithstanding, there are already several attempts to apply the model at the individual school level (for example, a high school in the same area, based upon IL02's rationale), and even at the municipal level in several locations.

At times an innovation's resources came from hi-tech companies, like in the case of IL03. Students with an ICT background were identified in the school and were offered adequate training enabling them to participate in the maintenance of the school's computers and in the construction and maintenance of the school web site. These students in turn served as tutors and aids for the teachers, and even participated in community projects such as the training of senior citizens or special education students in ICT use. The training was given by a hi-tech company during the summer vacation (with minimal payment on the part of the student). Such innovation demands only minimal effort from the school (i.e. to release computer trustees occasionally from their regular lessons), thus having good prospects of STS.

Discussion

ICT implementation in schools is a complex process, involving many factors (Pelgrum & Anderson, 1999; Venezky & Davis, 2002; Mioduser *et al*., 2003). The question about the extent to which ICT implementation has modified schools' structure and functioning has been controversial over the years (Cuban, 1986; Schank & Yona, 1991). Israeli schools present various examples of innovative practices using ICT that have created change in the school organization. Five such schools were examined in our study, within the framework of the OECD/CERI's international case study. Our goal was to map the scope and character of these innovations, the domains and aspects of the schools' life that had undergone changes, and

the prospects of these novel practices to be sustainable, transferable and scalable. In this section we elaborate on several overall issues based on the study's results.

Technological infrastructure. We have observed that 'innovativeness' in terms of the mere presence of advanced technology is not the sole issue. The innovative practices studied were based on the use of sophisticated technologies (e.g. IL05—virtual learning environments development) as well as commonly used tools (e.g. IL03—training senior citizens in word processing). Over the years, in Israel as elsewhere, public discussion on educational computing as well as policy decisions have overemphasized infrastructural aspects (hence directing resource allocation mainly towards equipment and services acquisition). Appropriate technological infrastructure is an obvious prerequisite, but other factors too significantly affect the appearance and sustenance of technology-based innovations: the vision and work of a devoted principal, a clear set of values and innovative culture inside the school, the involvement of external forces (e.g. competition with other schools, location), and support of parents and the community.

Islandness vs. school-wide innovations. We speculate that 'hard core' innovations like IL02—the 'school of the future', with all its unique features (the innovation is embedded in the building itself, in the staff training process and everyday behavior, in its organizational functioning) will evolve as more sustainable in the long term than innovations operating as 'islands' within more traditional settings. Islands appear to be more dependent on the ad hoc resources (human, material) involved in their inception and implementation. However, this speculation requires additional research in the form of a longitudinal study.

Policy issues. We have observed an interesting connection between scalability and policy issues at the national and municipal level. Potentially scalable innovations were found to be encouraged and supported by local and national decision-making agencies, such as municipalities and organizations linked to the Ministry of Education. An example is school IL04, which implements 'Beehive', an educational project encouraging communication and collaboration among students. Reflecting explicit national policies related to ICT implementation, the project has been activated in many schools with the extensive support of a non-profit organization and the endorsement of the Ministry.

Prospects for STS. The factors that appear to affect the durability of innovative practices (e.g. principal's vision, values, external support) are different from those needed to create it to begin with (environmental shock, isomorphism forces). Therefore, it is difficult to predict the scalability, sustainability and transferability of an innovation at its start-up phase. For

example, if observed at their planning or preliminary implementation stages it appears that IL03, the computer trustees project that is credited by the community and demands limited resources from the school itself, seems to be easier to sustain than IL05, the virtual learning environments development project demanding the allocation of important time resources and relying on the principal's time, devotion and vision. De facto, both innovations have entered the stage at which they are part of the school's culture and functioning. It should be noted here that all five Israeli innovations chosen were operative for at least 2–3 years, so that an appropriate estimation of their sustainability could be made.

Overall, given similar conditions (infrastructure, teacher development, budget), factors affecting the prospects for a high level of transferability and scalability were related to ease of implementation and use of the technology (favoring activities such as Internet navigation or use of e-mail); replication practicability (e.g. the use of standard commercial tools for developing virtual learning spaces), and external support (e.g. academic, pedagogical, funding). Inverse relationships were found between the level of innovation in given domains and the prospect for STS. For example, practices highly innovative at the pedagogical or curricular level (e.g. IL02, IL05) were considered as problematic candidates for transfer and scale 'as they are'. As a logical complement, practices which demanded little change in spatial organizational and functional configuration (e.g. IL03, IL04) were evaluated as highly transferable and scalable.

To conclude, a methodological remark: there is an apparent contradiction between statements about sustainability, transferability and scalability and the fact that this study was carried out at a fixed point in time, rather than a longitudinal study. However, responses from participants (some not as involved in the innovation as others, or even opposed to it) in interviews and questionnaires, along with the fact that the innovations had been in action for at least 2–3 years (a precondition in this study), have led us to substantial observations which, we believe, can serve as a solid background for the design of future systematic longitudinal studies.

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