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This paper describes a longitudinal study, in which the interaction between junior high school principals and science teachers is characterized, and its influence on technology implementation is explored. Fourteen principals and 19 teachers who participated in a former study, which took place from 1998 to 2001, were re-interviewed and observed during 2005. The teachers were classified into four types—*Initiators*, *Followers*, *Evaders* and *Objectors*—based on the mode and extent to which they implemented educational technologies in their teaching. Principals were also classified into four categories—*Initiating*, *Empowering*, *Permitting yet Preventing* and *Resisting*—based on the way they motivated or discouraged science teachers to incorporate educational technologies into their teaching. Findings indicate that the principals were fairly consistent in the type of support they provided to their teachers throughout the seven years of the study. The findings indicate that the principals' longitudinal support or discouragement plays a crucial role in teachers' ability and motivation to incorporate educational technologies as an integral part of their teaching. Encouraging outcomes show that teachers between the years 2001 to 2005 were somewhat less dependent on the principals' support than they were between the years 1998 to 2001.

Introduction

This study examines the effect of junior high schools' organizational environment as expressed by principals' attitudes and involvement on bringing about a pedagogical reform in the context of teachers' implementation of educational technologies. We based our definition of technology integration on Belland (2009) and Jonassen *et al.* (2003) who defined this term as long-lasting and continuous change in the school system caused by the adoption of technology to help pupils construct knowledge.

To put the study in context, we start with a brief description of a major reform in the Israeli science education in the 1990s, and a teacher professional development project which served as the basis for the current study. The major national reform in the Israeli science education of the 1990s was born from a critical report about the state of science education at that time

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(Harari 1994). One of the recommendations of the report was that science and technology should be taught with more emphasis on inquiry, using information communication technologies. As a result, the ministry of education devoted considerable funding for equipping schools with up-to-date hardware and software, and for professional development projects that would assist teachers to assimilate technology in their classrooms. As part of this endeavour science teachers in Israeli junior high schools (Grades 7–9) participated in continuing in-practice professional development programmes at the Technion—Israel Institute of Technology, where the current study took place. One of these programmes—a two-year teacher professional development project—focused on case-based teaching and initiated collaborative ways of working amongst 50 science teachers, empowering them and fostering development of new ideas and classroom practices (Dori and Herscovitz 2005). During the programme, the participating teachers went through a change in their abilities to carry on Web-based teaching—as described by Dori *et al.* (2002). The authors investigated the level of success in assimilating online activities developed by the teachers. The study included 67 science teachers in 16 schools, who were classified into four basic types of teachers: (1) The Initiator and Path-Finder; (2) The Follower and Conformist; (3) The Avoider (in this study we modified the term to Evader); and (4) The Objector—Antagonist. The researchers found that the quality and cohesion of the school teachers' teamwork and the principal's care and involvement were major factors in the implementation of educational technologies in the classrooms. The researchers described in detail the design of a comprehensive professional development programme, which included in-campus workshops, work group meetings and in-school support. They followed these teachers, documented their beliefs regarding Web-based teaching and analysed the artefacts they had submitted. The teachers communicated using an online forum. They worked in teams to develop Web-based learning materials which were then implemented in the teachers' own classrooms.

The current research builds on the studies described above and extends them with the objective to understand and explain the long-term effect of the principal's attitude on teachers' motivation or discouragement to continue to adopt and assimilate technology tools in their instruction. Similar to Belland's (2009) definition, we refer in this paper to the term technology integration by teachers as the level of breadth and depth of incorporating Web-based activities both for teaching in the classroom and for pupils' assignments. We briefly review the characteristics of the science teachers and the four types of teachers, based on their incorporation of Web-based teaching, as described by Dori *et al.* (2002). We then describe in detail characteristics and classifications of junior high school principals with respect to the way they motivated or discouraged science teachers to incorporate technology-based learning environments and activities into their classrooms. In this longitudinal study, we wanted to investigate the long-term effects of principals' attitudes to the deployment of educational technologies for pedagogical purposes. To this end, we returned after about four years to the schools where our original professional development and research had taken place and investigated the learning environment in those

schools from an educational technology infusion and a Web-based teaching and learning perspectives.

Research goals and questions

The goal of this retrospective research was to characterize the interaction between junior high school principals and science teachers and to explore the longitudinal influence of this interaction on technology infusion and implementation in the schools. To meet this goal, we set out to answer the following research questions:

- How and to what extent did teachers implement technology in their classrooms five years after participating in a two-year long technology-oriented professional development programme?
- What are the characteristics of the principals in terms of attitudes and level of support towards technology implementation during the seven years of the longitudinal study?
- What is the effect of the principals' attitudes on teachers' approach and level of educational technology implementation?

Theoretical background

A large body of literature has been devoted for several decades to the characteristics of principals who lead changes in their schools (e.g. Thomas 1978, Hall *et al.* 1984) and to the role of schools as environments that encourage the teachers' professional growth (Shulman 1997, Quinn 2002, Flanagan and Jacobsen 2003, Kelceoglu 2006, Demertzi *et al.* 2009). As many researchers have noted (e.g. Fullan and Miles 1992, Fullan 1993, Blumenfeld *et al.* 2000, Davis and Varma 2008, Varma *et al.* 2008), the success of innovative approaches to education in general and of utilizing technology in classrooms in particular is heavily dependent on the school's environment and organization and on the principal's attitude towards the proposed change. The principal is increasingly expected to take a lead role in supporting teachers to adopt technology-based innovations that support learning and instruction (Creighton 2002, Bowyer *et al.* 2008) for his or her school.

Indeed, the important role of principals on instructional practices in school have been documented in several studies. For example, Quinn (2002) found a strong correlation between principal leadership behaviours and the principal's instructional practice descriptors as a resource provider, an instructional resource, and a communicator. A wider perspective on principals' role can be taken from a leadership stance. Modern leadership models, such as participatory leadership (e.g. Somech 2003), claim that when a leader takes a facilitation rather than an authoritative role, and enables other people in the organization to take part in decision-making, people are more likely to cooperate in becoming actively involved in the organization.

The role of principals in supporting teachers to assimilate technology incorporation into schools has also been studied locally; in a study aimed to determine the correlation between the principal's leadership patterns and the extent of computer integration in Israeli schools. Sasson (1999), based on Bass (1985), claimed that principals' leadership behaviours can be categorised as transformational and transactional. Transformational leaders had strong motivation and set more goals in each component concerning technology integration. They expressed desire to learn and become more acquainted with issues that needed to be addressed in order to integrate computers into school, while the transactional leaders merely addressed technical issues when those needed to be taken care of.

At an international level, several studies have characterized types of leadership with regards to technology infusion into schools. For example, based on a study of school principals in New Zealand, Yee (1998) proposed five information technology leadership types: technology entrepreneur, technology caretaker, technology trainer, technology modeller, and technology learner. In a qualitative study of the principals in 10 technology-enriched schools in Canada, New Zealand, and USA. Yee (2000) further defined eight technology leadership types: equitable providing, learning-focused envisioning, adventurous learning, patient teaching, protective enabling, constant monitoring, entrepreneurial networking, and careful challenging. Our research did not get down to such fine level of resolution, as our spectrum was broader, ranging from Initiating principals, all the way to resisting ones.

The critical role of leadership for carrying out reforms has been widely studied. For instance research has shown that the most successful systemic reform efforts succeed where the local organization either invents or assumes ownership of the core ideas in the reform (Honey and McMillan-Culp 2000). In these reforms, principals often set goals and directions. However, research shows that in many schools, informal leaders emerged, often the teachers themselves, to take up the difficult task of planning for technology integration and supporting distributed efforts in school (Flanagan and Jacobsen 2003). Furthermore, researchers such as Judson (2006) claim that although principals' are those that are expected to build 'Technology Leadership' in their schools, ultimately, how effectively and how often the technology is used is heavily dependent upon individual teachers (Judson 2006). In the current research we sought to explore the strength of the influence that principals have on teachers in adoption and assimilation of technology in their teaching. For instance, we wanted to explore whether enthusiastic teachers are able to lead meaningful changes with regards to technology adoption, even without a strong support of a principal, or even when the principal had a negative attitude towards technology.

The previous research (Dori *et al.* 2002), which served as the basis of the current study, has laid out a theoretical framework for professional development of science and technology teachers who incorporate educational technologies and especially Web-based learning into their teaching. The research has also indicated that the extent of technology assimilation and continued teacher's professional development depended on the support of

the school's principal. The research by Dori *et al.*, has also identified four types of principals: (1) The *Initiating* principal, who defines and leads change processes and mentors the required organizational changes; (2) The *Empowering* principal, who seeks to apply technology-based instruction and supports various teacher initiatives in this direction, but does not lead the required pedagogical reforms; (3) The *Permitting yet Preventing* principal, who theoretically approves technology-based instruction, but does not support the organizational infrastructures that are required for successful application; and (4) The *Resisting* principal, who, for various reasons, objects any element of technology-based instruction. However, that research focused on processes that teachers went through and not on the longitudinal effect of the principals' support on teacher practices.

Methodology

Our research is longitudinal in nature, spanning a seven-year period between 1998 and 2005. We refer to the period between the end of the teacher professional development project (2001) to the retrospective interviews (2005) as the longitudinal study, and to the period examined between the years 1998–2001, in the original study as the TPD (Teacher Professional Development) period. To examine the changes in teachers' attitudes and practices in technology implementation in the longitudinal study and to compare these changes to the TPD period we collected and analysed data by employing the constructivist and interpretative method (Denzin and Lincoln 2000).

Participants

To obtain the retrospective data, we were able to reach and interview 14 principals out of the original 16 principals from the Dori *et al.* (2002) study. In addition, we succeeded to reach 19 out of about 60 teachers who participated in the original study and were still employed in these 14 schools.

Tools and analysis

Interviews. Each of the principals and teachers were interviewed for about one hour, during 2005 (a total of 33 interviews) using a semi-structured interviewing technique (Denzin and Lincoln 2000). The interviews took place in the schools. All participants were asked whether and why they think that incorporation of technology into school teaching is beneficial, and what they do to enhance technology use in their schools. Teachers were encouraged to talk about their use of technology for instruction, and to illustrate, using a computer, which was present in the room during the interview, some of the technology-based activities that they have used. Principals were encouraged to discuss their role in supporting technology

Table 1.   Types of teachers regarding their attitudes towards technology

Teachers' types	Characteristics
The Initiator and the Path-Finder	Will apply Web-based inquiry teaching in any and all instances; an autodidact, and can find ways to cope with technical and organizational difficulties to apply technology-based instruction; finds his/her own way to improve teaching skills and incorporate Web-based inquiry activities in the classroom.
The Follower–Conformist	Participates in courses about Web-based teaching and is exposed to such activities; will apply Web-based teaching when it is suitable and convenient; Web-based inquiry learning is not viewed by him/her as extremely relevant to students.
The Evader	Has agreed to utilize some aspects of Web-based teaching but will not initiate anything in his/her school in order to do so; will use Web-based teaching only when required.
The Objector–Antagonist	Would not use technology-based instruction under any condition; has 'his/her reasons' for not utilizing computers or the Internet and unfamiliar with advances in information technology (mostly tenured teachers towards their retirement).

use by teachers. All interviews were audio recorded and transcribed. The collected data were first read and processed, listing significant words, phrases, and sentences. Data were then categorized, focusing on the teachers' and principals' technology adoption. To enhance academic rigour, all transcripts and documents were independently read and interpreted by two science education experts. Throughout the analysis process, the suggested categories and insights were examined and discussed until consensus was achieved.

Rubric for classification of teachers' attitudes. The two rubrics developed by Dori *et al.* (2002) for characterization of teachers' attitudes towards incorporation of technology into school (Table 1) and principals' support for this process (Table 2) were used to reclassify the characteristics of each of the teachers and principals as represented in the retrospective interviews.

Table 2.   Types of principals regarding their support for teachers in using technology

Principals' types	Characteristics
The Initiating principal	The principal leads the process of change, identifies the need, defines it and mentors the required organizational changes.
The Empowering principal	The principal is interested in change of teaching methods and would like new endeavours, including Web-based teaching, allows teachers to proceed with their initiatives.
The Permitting yet Preventing principal	The school principal seems to support Web-based teaching initiatives, but persists in his conservative policy as to school's timetable, lesson structure and curriculum.
The Resisting principal	The school principal knowingly objects to any teaching method that involves Web-based elements of any kind. The reasons may differ, but by and large, they are linked to religion and tradition.

Findings

In this section we first describe the processes that principals and teachers went through in the longitudinal study, and use these findings to analyse the effect of principals on teachers in this period. Then, we compare these findings with similar findings that we have elicited from TPD period. The comparison enables us to draw conclusions regarding changes in patterns of principal–teacher influence, over a long time period (seven years).

Change patterns in the longitudinal study

Teacher–principal matrix. To illustrate the relationship between principals' support for teachers and teachers' attitudes in the longitudinal study, we constructed a matrix (Figure 1), in which each cell indicates the level of support from principals on one hand, and teachers' attitudes, on the other. Each of the 19 teacher/principal combinations was plotted on the matrix to illustrate the situation between the years 2001 to 2005. Shifts within each of these years were represented by arrows on the matrixes and stability between the years was represented by circles. In this manner the matrix illustrates the dynamics in teachers' attitudes towards incorporation of technology in their teaching within this period, and the relation of their attitude to the principal's support. Figure 1 shows that in this period all 14 principals stayed consistent in the type of support they provided to teachers with respect to incorporation of technology in their schools (none of the arrows crosses rows, they only cross columns).

In particular, three principals (O.M., D.A. and E.N.) who were identified in the original study as Initiating principals continued to lead the process of change and fully supported teachers in carrying out this change. Five principals (Y.Z., M.H., Z.Z., S.K. and B.B.) continued to take a role of an Empowering principal and allowed teachers to proceed with their initiatives. Four principals (S.H., L.G., R.L. and T.F) sustained their Permitting yet Preventing ambiguous approach towards technology use in the classrooms. The remaining two principals (Z.G. and Y.E.) were of the Resisting type and stayed so throughout the longitudinal study.

In a number of cases, the approach of the principals became somewhat more extreme (in either a supportive or a non-supportive approach). For instance, in one case, a principal (O.M.) who had been defined as an Initiator in the former study became even more supportive during the five years of the study. O.M., who introduced the use of computers for teaching and learning in her school seven years ago, claimed in an interview in the original study in 2001 that although she believes technology should be integrated into all teaching and learning activities in school, she does not hold a personal computer on her desk (Peled 2002). In the follow-up interview in 2005, there was a personal computer on her desk which she used for administrative and personal purposes. O.M. explained that in time, the demand to answer teachers' emails, and respond to pupils' postings on the school website, forced her

'to join forces with the teachers and take part in the fun ...' She claimed that '... Once that happened, I was encouraged that the process I was leading is the right one'

O.M. also explained how technology became an integral part of the school activities. She mentioned that a person who was hired to lead the process under her supervision was necessary only at beginning stages and that after she moved to another school, the process naturally continued in the school

> the concept of using computers in everyday school-life was so deeply rooted, that the teachers just carried on with their work ... Through the years a new generation of teachers who used technology as a pedagogical tool and could mentor other teachers developed.

In another case, a Resisting principal became more confident in his resistance to incorporating technology into his school. Y.E. is the principal at a high school for girls. The technology facilities in the school include a computer lab and one more computer in the science classroom. An example of Y.E.'s discomfort from technology is represented in the following excerpt from an interview in 2005:

> The computers here haven't been upgraded since 1999, there's no money for it from the municipality ... now, even if I had the money I will not spend it on computers as I did years ago when I was persuaded to accept computers from the ministry of education. That was a mistake. We can do much better without them. There are other instructional tools much less dangerous than computers.

Unlike the principals, the teachers' approach to technology-based instruction changed considerably during these seven years. We claim that this change is related to the principals' type of attitude and support. Figure 1 summarizes the evidences for this claim using the matrix framework described above.

In the sequel we describe three general processes of change that teachers went through: (1) advancement, (2) no change, and (3) pullback in the way they incorporate technology. As can be seen from Figure 1, the Initiating and the Empowering principals (first two rows in the matrix) caused some of the teachers to advance to higher levels of technology implementation, four teachers progressed, and six stayed in the same level of commitment. On the other hand, the Permitting yet Preventing and the Resisting principals (Rows 3 and 4 in Figure 1) caused teachers to regress; only one teacher continued to use technology with the same passion, and eight retrograded to lower levels of technology use. To illustrate these shifts we describe below eight patterns of change in teachers' incorporation of technology in their teaching, identified in this study and delineated by roman letters in Figure 1.

Pattern I. This pattern represents teachers who were described as Initiators and taught in schools with an Initiating or Empowering principal (pattern represented as Ia for Initiating and Ib for Empowering principals) benefited from the principals' attitude and continued to develop their use of technology for teaching. One example of pattern Ia is teacher G.J. (principle E.N.). In the original study G.J. was identified as an *Initiator*. During the

professional development course she showed great enthusiasm about using computers in her classroom. After four years she retained her excitement and developed additional ways to use technology to expose her pupils to online learning materials, to improve her dialogue with the pupils via forums and email and to incorporate online feedback. In the follow-up interview she claims that

> The school supported all my computer-based activities … the support included flexible class hours, and enabled me to use non-traditional web-based evaluation methods.

Another Ia example that illustrates the importance of the principal's support in this pattern is an excerpt of P.D., a science coordinator and a teacher in another school (the principal was O.M., described above as an *Initiator* type of principal). When interviewed in 1999, P.D. was somewhat hesitant about the principal's commitment and vision for technology use in school. In the current study she says:

> Now, after so many years of consistent efforts on behalf of O.M. to lead the school to where she believes it should go, there's a definite change in teachers' attitudes toward incorporating technology. For myself I can say that the school's attitude enables me to explore new ways of teaching and enables me to invest time in developing curricular materials that make a good use of the technology available for teaching Science and Technology.

Most of the Initiating teachers who worked with Empowering principals went through similar processes (Ib). One example is S.C. (principal S.K.), a physics teacher, who started building her own online learning materials during the professional development course in the early study. In the follow-up interview, she presented a rich physics website that she developed, which included online expert lectures, Web-based instructions for conducting hands-on lab activities (e.g. mathematical pendulum, capacitor charging and discharging, photoelectric effect, Rutherford model), links to enrichment physics websites, collaborative activities and example tests and their solutions.

Pattern II. This pattern represents teachers who were described as Followers in the previous study and were found as Initiators in the current study. IIa describes this pattern when the principal was described as Initiating, and IIb describes it, when the principal was Empowering.

An example of a IIa pattern is D.H., a science teacher working with the principal D.A. (an Initiator type of principal). D.H. was characterized during the 1998–2001 research as a Follower. Her participation in the teacher professional development programme at the Technion was enforced by D.A. who demanded that all teachers will acquire basic know-how of computer use for teaching. In an interview in 2004 she says,

> I wasn't much interested then in computers, I had other things on my mind then … D.A. the principal insisted that I'll attend the course … Implementing what I've acquired in the workshop was not easy, but I received support all along the way. During the first few months after the course, my mentor from the Technion, came into school regularly to work with me, he was available through mail and telephone. The most important element for me in those months was the school atmosphere, which was determined by the principal. He made it clear to all the staff, that school has to make sure that teachers will have all the support needed to incorporate

educational technology into their teaching. This attitude allowed me to gain confidence in this new environment. In time I became more and more competent—today I'm an expert. I conduct regular interactions with my pupils through my forum, I run the schools' science and Technology web site.

In the retrospective interview D.A. emphasized that he gave all the teachers technical and emotional support in the process of incorporating technological innovations in their classrooms. However, he added:

> Those who were not ready for this painful but satisfactory process are not teaching in our school nowadays.

An example of a IIb pattern is S.A., who was not categorized as an *Initiator* type during the 1998–2001 research. She teaches high-school biology and junior high school level science and technology. S.A. is highly respected by the principal (B.B.), who according to our classification is an Empowering principal. During the retrospective interview, the principal describes S.A. as 'Initiative, optimistic and most positive'. She also mentioned that she made a great effort to satisfy all her needs with regards to administrative requirements 'anything that S.A. asks for is taken care of'. The retrospective interview with S.A. indicated that she feels that she has a lot of support from the school.

> During the last few years, this positive environment allowed me to pursue new curricular activities and programmes designed to enhance motivation for learning. The use of computers was part of it, and today I feel that I have the knowledge and capabilities to utilize it as needed.

Pattern III. Y.H. represents an Evader type of teacher, who became a Follower when working with an Empowering principal (Z.Z.). In the follow-up interview Y.H. claims that during the last few years the school's attitude towards incorporating educational technology has not changed, but that the environment has changed and brought him to incorporate more technology uses to his teaching:

> Computers are everywhere … The pupils are computer literate… As head of the environmental studies at school, it's my responsibility to lead changes, including the use of new teaching techniques, new curricular materials … There are regional and international projects which are very attractive; they are all Web-Based activities … We acquired a computerized meteorological station … We compete for awards and grants from the Ministry of Environment and education, which means writing papers, building presentations … All in all I found myself working with the computer as part of my daily routine.

Although teacher Y.H. claims that the larger use of technology in his teaching is influenced by environmental factors (projects that the school is involved with, new hardware, etc.), and although he does not mention the principal as a factor, our interpretation is that the activities and infrastructure that Y.H. mentions are supported by the school's principal. A principal who is not *Empowering* would not encourage applying for funding for technological updates or new projects.

Pattern IV. This pattern represents teachers who were classified as Objectors. These teachers did not change their attitudes, even when they worked with empowering and Initiating principals. An example is Y.O., a

teacher who was originally defined as Objector and consistent in this attitude.

The opposite effect, in which teachers decreased their use of technology when working with the Permitting yet Preventing and the Resisting principals, is illustrated by Patterns V–VIII. To illustrate this effect we describe one case representative of Pattern VIb. This pattern shows that in a school in which the principal resists the use of technology, even an Initiating teacher is likely to gradually lose the drive to be an Initiator or Follower of technology-based projects in school. For example, Y.B. works in a school with a principal which we categorized as Resisting (principal Y.E.). In 1998, Y.B. was clearly classified as an Initiator who worked in a school with principal which we categorized as a Resisting type. During the professional development training she developed a course website and discussion board for her environmental studies classes and asked her pupils to respond to web-based assignments she designed. However, towards 2001 Y.B. was already categorized as a Follower due to the obstacles she faced in her school. In the retrospective interview Y.B. claims that her efforts to incorporate computers into the environmental studies are 'shattering against the wall of objection' she continues that

> There are no sufficient facilities. Years ago the principal disconnected the computers from the Internet, he said there's no money to pay the bills … I'm very frustrated and angry. You already heard that from me two years ago, but then I believed that in time the principal's attitude will change … now I just know it will not … I do not commit myself to anything new. I have no more energy.

Her ongoing frustration and lack of resources or school support pushed her towards being Evader in 2005.

We found one exception of a teacher (A.A.) who continued to act as an Initiator even though the principal T.F. acted in a Permitting yet Preventing manner, as indicated in by Circle V. It is important to note that in between the original study and the current retrospective study, A.A. studied in a PhD programme. Her research topic was related to the integration of computerized laboratories into high school chemistry (Abed and Dori 2007). In both interviews with A.A, it was evident that she is a strong-willed person who has got her own agenda concerning the way her teaching is done.

> The principal knows I'm stubborn, he appreciates me as a professional, he knows that when I make up my mind about something I will do it, so he allows me to teach the way I want. He even found the money to purchase Computerized Labs-kits for me to match the Ministry of Education Small Grand which I received … I'm determined to continue fighting for what I believe in. Currently I need the principal permission to allow me to teach in small groups, I'll talk the principal into giving his consent to split my class to small groups so they'll be able to work in the computer lab and make a good use of the kits.

In summary, the findings of the longitudinal study showed that a principal who has been supportive and encouraged her teachers—the Empowering principal—was able to bring all the types of teachers, except the Objector, to advance in their Web-based teaching activities. Conversely (but similar to the TPD study), a principal who has been preventing his teachers from engaging in computerized teaching activities—the Resisting

principal—stalled progress even of the Initiator and Follower teachers, and most of them declared they stopped their computer-enhanced teaching activities.

Comparison between the two periods

To gain deeper insight into the relationship between principals' support and teachers' attitudes towards incorporation of technology into their teaching, we used data from the Dori *et al.* (2002) study, to construct another matrix, similar to the one described above, for the TPD period (Figure 2). With both matrixes at hand we were able to compare the change processes in both periods. The comparison revealed a different pattern in the dynamics of teachers' attitudes, as they relate to the type of support they received from principals as well as a few similarities.

The main difference between the two matrixes is evident in the second row of the matrix, representing schools in which the principal was classified as Empowering. In Figure 1—the longitudinal study—all arrows in the second row point to the left, indicating a positive shift towards attitudes more favourable of technology incorporation. However, in Figure 2—the TPD period—all arrows in the second row of the matrix point to the right, indicating a negative shift. This means that in the TPD period, when teachers categorized as Initiators or Followers faced an Empowering principal (e.g. A.D., S.A., Y.H.) they felt that their efforts are not in line with school efforts and, therefore, reduced their time and energy investment in incorporating
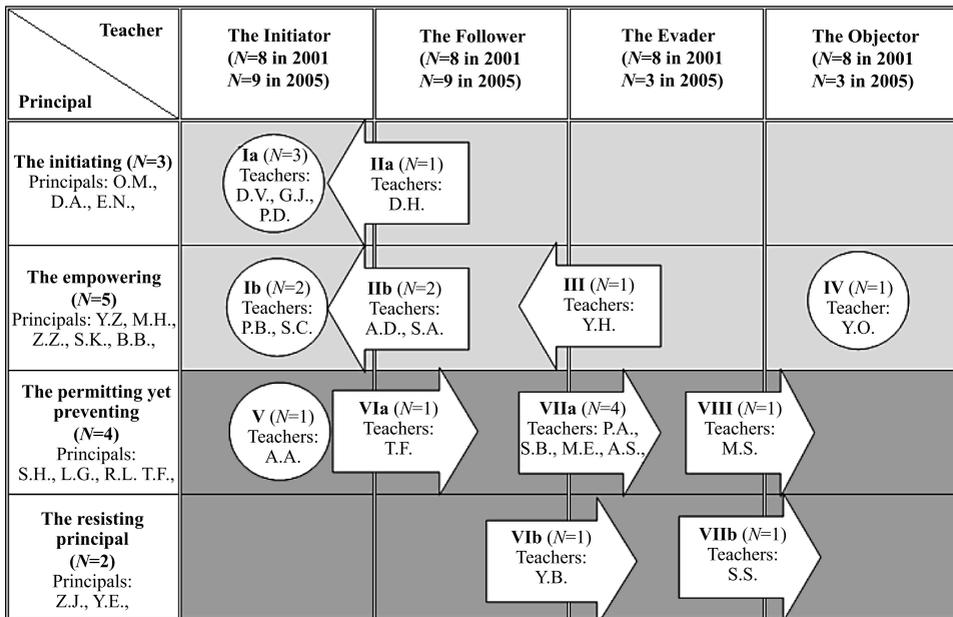
Figure 1.   Teacher–principal matrix between the years 2001 and 2005
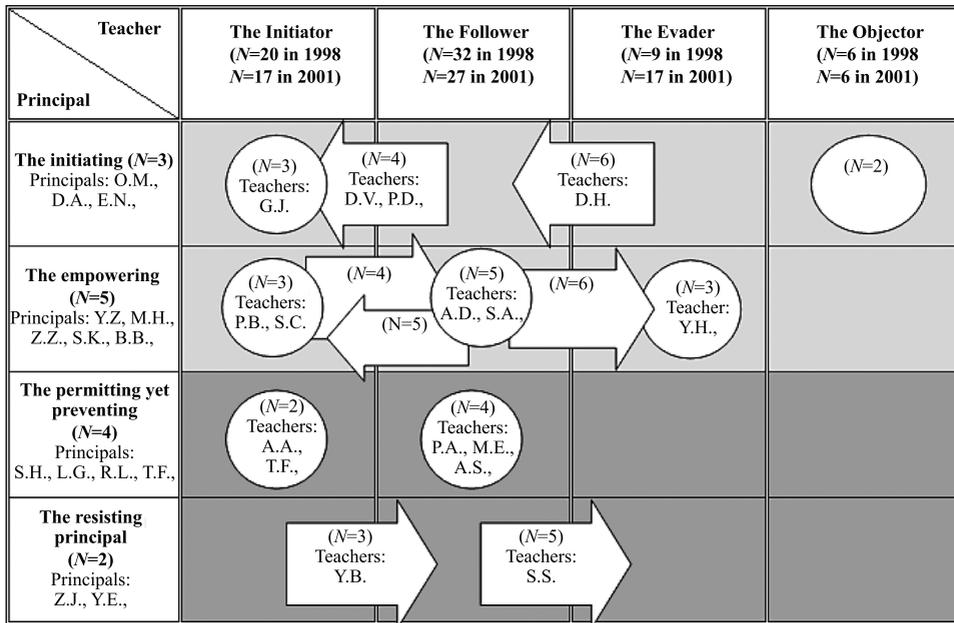
Figure 2. Teacher–principal matrix between the years 1998 and 2001

Web-based teaching. However, in the longitudinal study, these teachers viewed their Empowering principals as more supportive and the depth and breadth of the technology integration grew accordingly.

Discussion

We start this section with describing similarities and differences between our longitudinal study and the TPD period. We then provide additional support for our claims from the literature, and finally, we bring a few recommendations for school principals, who are interested leading meaningful changes to productively incorporate technology into their schools.

The comparison between Figure 1 and Figure 2 shows that several similar patterns characterize both the longitudinal and the original study. In both studies we saw that when working with an Initiating principal, a Follower teacher tends to become an Initiator and an Evader tends to become a Follower. On the other hand Permitting and Resisting principals were shown to cause the opposite effect in both the original and longitudinal studies—they demote the type of a teacher to a less 'advanced' type. In schools in which the principal resists the introduction of technology, even an Initiator teacher gradually loses her drive and desire to put in extra effort. In such schools the teachers often get a feeling of 'fighting windmills'.

However, one important difference we found between the processes represented in Figure 1 and Figure 2, they indicate a change that occurred throughout the seven years of this study; in the original research we found that only the Initiating principal was successful in advancing teachers, while

teachers who worked with the Empowering principal stayed at the same place or even regressed. However, in the longitudinal research we found that an Empowering principal is sufficient to advance teachers' use of computers in their teaching activities.

But before we discuss this important difference, we turn back to our findings regarding the influence of the principals' leadership on teachers' attitudes towards assimilation of technology. These findings are in accordance with several other studies (e.g. Foster *et al.* 2000; Supovitz and Turner 2000), some of which were even conducted in the Israeli arena. For instance, Bogler and Somech (2004) showed that teachers' perceptions of their level of empowerment are significantly related to their feelings of commitment to the organization.

The principal types identified and characterized in this research provide a basis for predicting teachers' implementation of technological innovations in general, and Web-based teaching in particular. We showed that even if a teacher is not aware of the fact that her activities depend on her principal's attitude (as was the case with Y.H.), this is still so. The principal creates the basis upon which teachers can flourish (or be suppressed). However, the differences found in this study between the longitudinal study and the TPD period indicate that other factors, which changed over time are involved as well. It is very likely that throughout the seven years of the study, external factors such as the use of technology in the everyday life of all those involved in the school community (pupils, parents, teachers, and administrators), created an atmosphere in which teachers became less dependent on the leadership of their school principal. This is in line with literature from the 1980s, such as studies by McNeil (1986, 1988), which showed that in general (not only with regards to the use of technology), teachers are more likely to appropriately implement their professional knowledge when external factors such as conflicts with administrative policies are involved.

That said, we find it interesting that in spite of the penetration of technology to many life domains, including the educational system, the principals in this research did not undergo a significant change. One reason for this might be that they were not required to be active partners in the TPD process in the original study (they were only required to free the teachers for one day a week during the three years of the TPD). Whatever the reason for this might be, this study shows that although budgetary support was provided throughout the process, and in spite of the massive guidance along the three years of the research, when principals of the two lower levels were involved, the process was much less successful. We would like to note that since the reform was comprehensive, and not selective, all principals whose teachers were involved in the TPD were involved in the process. The requirements from them were minimal and their readiness was not examined beforehand.

Our recommendations for school principals who seek to lead meaningful processes of technology assimilation in their schools are twofold. First, based on our results and other studies (Bowyer *et al.* 2008, Varma *et al.* 2008), principals should become more involved in teachers' professional development and further updated in new and innovative programmes. It is important that school principals encourage their teachers to carefully choose

well-designed and affective ICT-based curriculum. A previous study showed that what essentially limit innovation are not so much the deficiencies in terms of infrastructure or training but the curriculum per se (Mueller *et al.* 2008). A second recommendation is that principals should select teams which consist of teachers with potential to make best progress and lead curricular changes in the context of educational technology implementation. Studies show that hands-on, direct practice with information communication technology in a teacher's own classroom or teaching context builds the confidence necessary for her/him to take the risk of including technology within their teaching repertoire (Fishman *et al.* 2003, Shamir-Inbal *et al.* 2009). Success may come in the form of personal hands-on experience and it may also include vicarious modelling by other teachers having successful experiences in their classrooms (Fishman and Krajcik 2003).

Our longitudinal study and its recommendations raise two open questions:

(1) Can (and to what extent) the involvement of school principals in TPD programmes affect their cooperation and willingness to support and lead technology-enhanced learning in their schools? In other words, can the Permitting yet Preventing principals, whom we found to have an ambiguous relation to technology usage in education, advance to a higher level of support if she or he is actively engaged in the teacher training process?

(2) One of our findings indicates that as time passed, teachers at the highest level—the Initiators—even if they worked in a non-supportive environment were able to find channels to lead a process of change in the educational system and academic research. This finding leads us to the following question: Whether and to what extent this process in which teachers will become less and less dependent on the principals support will continue? In other words, can teachers under a Permitting yet Preventing principal or even a Resisting principal make progress? If so, what are the supportive circumstances? Are the supportive circumstances external (pupils, parents, national standards, penetration of computers to other life areas, etc.) or internal (personality, self-confidence, self-efficacy, etc.) or a combination of both?

Finally, we would like to note that there are several limitations to this study, the small number of participants, the wide variety of personal and context characteristics, and the diverse configuration of Web-based tools. These limitations weaken the generalization power of the study. However, we believe that this study provides a basis for further research and raises important questions that will promote a growing body of knowledge on sustainable science curriculum innovations and the integration of educational technologies into the science classrooms.

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