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Aptness between Teaching Roles and Teaching Strategies in ICT-Integrated Science Lessons

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Abstract

Teachers' perceptions about their roles may serve to support or oppose the integration of new practices while using Information and Communication Technologies (ICT). To investigate this assertion, we followed the work of six leading teachers in their classrooms during a period of one academic year. By applying the descriptive-interpretive methodology we examined the teachers' role perception and their teaching strategies. The research tools included teachers' interviews, classroom observations, and an aptness matrix that was specially developed for this study. The qualitative analysis focused on four literature-based categories that indicate teachers' roles: guide, motivator, partner, and innovator. In addition, the analysis focused on four constructivist teaching strategies: visualization, problem-solving, inquiry, and reflective learning. Findings indicated that in the ICT lessons, teachers mainly act as guides and motivators while applying two teaching strategies: visualization and problem-solving. Only few teachers felt as innovators and only one teacher applied reflective learning. We demonstrate how the aptness matrix corresponds to the ACOT model for teachers' assimilation of ICT and how it can help teachers identify their own level of ICT implementation while promoting constructivist teaching and learning in their classrooms.

Keywords: Constructivist teaching and learning, Information and Communication Technologies (ICT), Teacher roles, Teaching strategies

Introduction

The development of information and communication technology (ICT), such as e-books, smart phones, and Web 2.0 applications, has caused far-reaching social and economical changes (Kraut et al., 2002) and recently instigated political shifts. In the past two decades, there has been a growing understanding of the important role of ICT, not only for business and economics, but also for learning and teaching (Barak, & Rafaeli, 2004; Dori, Barak, & Adir, 2003). Advanced technologies are evermore integrated into the classrooms, having the potential to become an integral component of today's education, as well as to

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change the way class communication and information flows (Barak, Lipson, & Lerman, 2006). The development of rich multimedia and diverse web-based platforms led to the development of advanced educational technologies, enabling the implementation of innovative teaching methods that are based on constructivist and social constructivist approaches (Barak, 2007; Ben-Zvi, 2007; Roseth, Garfield, & Ben-Zvi, 2008). These approaches maintain that knowledge cannot be transferred; it has to be constructed in one's own mind. They also maintain that learning is a socially-mediated experience for which individuals construct knowledge based on interactions with others.

As educational technologies and new learning methods evolve, teachers are expected to adopt and assimilate rich and exciting learning environments. However, research shows that, although many teachers are aware of the educational potential of integrating ICT, a considerable number of them do so in a traditional, teacher-centered manner with no significant change in their teaching strategies (Bransford, Brown, & Cocking, 2000; Cuban, 1993). In order for an educational change to occur, teachers' perceptions and beliefs should also be changed. Teachers' beliefs and world-view have a great influence on the teaching methods and strategies they use (Davis, 2003; Handal & Herrington, 2003). Accordingly, teachers' perceptions of their roles may serve to support or work against the implementation of new ICT practices. The current study examined this claim by investigating whether there is aptness between science teachers' perceptions of their roles and the teaching strategies they use in lessons integrating ICT.

Literature Review

The literature review comprises of three sections. The first section details the roles of science teachers as described in various studies and in national reports. The second section describes different teaching strategies that promote constructivist teaching and learning. The third section focuses on the assimilation of advanced technologies in teaching, emphasizing the teachers as key agents in promoting changes and integrating ICT into the educational system.

Science Teachers' Roles

The standards in the field of science teaching emphasize the need for science teachers to use strategies that develop deep scientific understanding while applying research skills and problem-solving abilities to complex questions (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). According to these standards, the science teacher's roles are to encourage the construction of new knowledge based on that previously learned and to help students take responsibility for their learning. The science teacher should promote learning by encouraging discussion among learners, fostering cooperation, and creating a learning community. The standards recommend teaching with the assistance of colleagues from the sciences and other academic fields in order to connect science teaching with additional disciplines, such as technology, languages, and the social sciences (AAAS, 1993; NRC, 1996). A review of the literature points to four main roles for the constructivist science teacher: guide, motivator, partner, and innovator. The following paragraphs provide the definition and characterization for each role.

Guide – a teacher that advances students, individually and as a group, in carrying out objectives determined at the beginning of the lesson. As a guide, the teacher decides when to intervene in the learning process and when to ask learners to clarify and critically examine their own work (NRC, 1996). The guiding teacher allows learners to express ideas and ask questions in order to assess their understanding and the nature of their work and to help them progress in accordance with their abilities (Crawford, 2000).

Motivator – a teacher that promotes students' motivation to learn sciences. As a motivator, the teacher is expected to encourage students' positive feelings about learning sciences and their natu-

ral curiosity. The motivating teacher is expected to help students start the learning process and maintain it. Students differ one from another in ability, learning style, personality, and intellectual inclinations; students without internal motivation have many difficulties in learning (Palmer, 2009). Therefore, the motivating teacher should adopt varied teaching methods to encourage learners' internal motivation, which derives from their interest in and enjoyment of the topic of study.

Partner – a teacher that acts as a partner to her/his students and colleagues in the learning process. The teacher as partner is an active member in a learning community that includes students and other teachers. The partner teacher is dedicated to share knowledge while studying with members of a professional staff (Crawford, 2000; Sandholtz, Ringstaff, & Dwyer, 1997). As part of a life-long learning community, partner teachers are dedicated to connecting scientific issues with other disciplines along with students' daily lives, thus making the learning materials relevant and significant to the learners (Barak, Carson, & Zoller, 2007).

Innovator – a teacher that applies new teaching methods and evaluates herself while examining students' understanding of the topic (Crawford, 2000). The teacher as an innovator is ready to implement new teaching initiatives and to integrate advanced technologies in education, while being aware of the advantages and disadvantages that these innovations may bring to the teaching process (van Braak, 2001).

Teaching Strategies

In this study, teaching strategies are conceptualized as tools to be used in designing and implementing instruction in a way that supports and enhances students' learning. In the literature, teaching strategies are referred as teaching methods or instructional techniques. They are defined as the ways teachers choose to achieve the goals they have set in their lessons (Schroeder, Scott, Tolson, Huang, & Lee, 2007). Tan and Chan (1997) call for teachers to apply advanced strategies and build into their subject curriculum the skills necessary to promote meaningful and effective learning. Although their study focused on preparing learners to learn in a self-instructional mode of learning, they indicated that teaching learning skills should be seen as the most basic and important teaching strategy and objective, especially in an ICT learning environment. Indeed, teachers' knowledge of teaching and learning strategies is most important since it ultimately determines student's performance and achievement.

Our study focused on four teaching strategies that encourage constructivist learning: visualization, problem solving, inquiry, and reflective learning. The strategies are defined according to the type of learning they promote in the classroom.

Visualization Strategy – provides students with activities that are aided by visual representations, such as models, animation, and graphs, in order to make the abstract more concrete and to clarify scientific principles and concepts (Barak & Dori, 2005). Visualization can help teachers and students present thoughts, discuss different ideas, and share knowledge. Students can learn from building, critiquing, and manipulating physical and virtual models. In this way, it is possible to encourage learners to develop their understanding of scientific ideas through the creation of mental models (Tversky, 2005).

Problem-solving Strategy – presents the students with open and complex problems to solve, preferably, authentic problems taken from the students' daily lives (Ertmer et al., 2009). Unlike regular 'drill and practice' exercises, problems have several possible solutions and several possible ways to be solved. Problem solving requires higher order thinking skills such as critical and analytical thinking for their solution (Barak, Ben-Chaim, & Zoller, 2007). Problem solving demands that learners take several alternatives into account and that they provide a reasoned argument supporting the solution they reach (Barak & Dori, 2005). It is generally carried out in cooperation

with peers, with each contributing to the group's knowledge according to his or her ability, so that at the end of the process the group will reach a reasoned solution together.

Inquiry Strategy – provides students with activities that develop knowledge and understanding of scientific ideas, as well as understanding of the ways in which scientists learn about the world (NRC, 1996). Inquiry-based learning provides learners with opportunities to experience scientific thinking while searching for answers to phenomena they find meaningful. Teaching that encourages inquiry-based learning in the sciences is likely to include a personal and a group research project, laboratory experiments, nature study through field trips, and analysis of scientific research studies (Tamir, Stavy, & Ratner, 1998). Learners in an inquiry-based learning approach are likely to develop critical thinking and acquire expertise in argumentation and reasoning, thus construct knowledge that leads to deeper understanding of scientific principles.

Reflective Strategy – encourages students to perform a formative internal evaluation to improve their own performance, during or after the experience itself. Reflection is conceptualized as the process of internally examining and exploring an issue of concern, triggered by an experience, which creates and clarifies meaning in terms of self and which results in a changed conceptual perspective (Boyd & Fales, 1983). Learning as a reflective activity means learning during which students look within at their own learning (introspection), identify and interpret new situations that evolve in the course of learning, criticize the process, consider it anew in discourse among themselves and with others, and react appropriately to feedback received from various sources (Henderson, Napan, & Monteiro, 2004). These actions enable students to examine their course of action as opposed to alternative ones, to reformulate their previous knowledge, to suggest solutions that they did not think of at the preliminary stage of planning, and to create new understandings and concepts (Eyler & Giles, 1990).

It is both possible and desirable to use all of the teaching strategies described in this section with the assistance of ICT, to support learners' affective and meaningful learning. The use of advanced technologies is likely to facilitate complex information processing and knowledge construction through visualization, problem solving, inquiry, and reflection.

The Assimilation of ICT in Teaching

The integration of ICT in education is a long process that calls for changes in work habits, in teaching methods, and sometimes also in the teacher's world-view. During years of work, teachers adopt instructional methods that are based on knowledge, perception, beliefs, and values. These factors affect the manner in which teachers teach and the way they react to educational change. For teachers to internalize the need for change, they must be dissatisfied with the existing situation and must have reached the conclusion that the particular way in which they work is not sufficient or is too conservative (Davis, 2003). Indeed, the development of Java, Flash, and other dynamic web-based applications assists teachers in presenting complex concepts and enhancing cognitive processes. However, unfamiliar teaching methods and the time investment needed to learn how to integrate ICT effectively into learning activities are some of the barriers to the assimilation of Web-based teaching and learning in university and schools (Rambe & Ng'ambi, 2011).

Different models of ICT assimilation can be found in the literature. One example is the five-stage ACOT (Apple Classrooms of Tomorrow) model (Sandholtz et al., 1997). This model relates to the changes taking place in a teacher's instruction in each of the stages that follow the assimilation of ICT. This model was chosen to represent the assimilation process in the current study as it refers uniquely to teachers' integration of new technologies. The ACOT model includes the five stages described in the following paragraphs: Entry, Adoption, Adaptation, Appropriation, and Invention.

Entry – the teacher's first experience with the new technology, learning how to set up equipment and operate it. At this stage the teacher feels uncomfortable using ICT and usually doesn't use it for instruction. She continues to use well known traditional instructional activities.

Adoption – the teacher starts to integrate technology to support traditional instruction. The use of the technology is only for drill and practice activities. In this stage the teacher starts to feel safe in the usage of technology and the way the classroom is organized. The teacher starts to understand the need for changes that are induced from the integration of technology in her instruction. At this stage she still doesn't make significant changes in the manner of her instruction.

Adaptation – the teacher starts to integrate technology into the curriculum and recognizes that the integration of technology enhances students' understanding and leaves time for a broader learning experience. The teacher internalizes that she has to change the way she teaches and the way she evaluates the students' work.

Appropriation – in this stage the teacher can't manage without the computer. The teacher is well familiar with ICT and is able to teach in new ways. She uses the option of communication and collaboration that ICT provides, such as electronic forums and chats. Her students become active and involved in the process of learning.

Invention – the teacher is able to design new learning environments in order to use them and make important changes in instruction and learning methods. The teacher begins to develop different uses for technology and creates projects that combine two or more technologies.

Research Goals and Questions

This study examined science teachers' role perception and their teaching strategies while using ICT in their classrooms. The following research questions derived from this goal:

1. How do science teachers perceive their roles in teaching that integrates ICT?
2. Which teaching strategies do science teachers use while integrating ICT in their classrooms?
3. Is there aptness between the science teachers' role perceptions and the teaching strategies they use while integrating ICT?

Participants and Research Method

Six leading science teachers from six secondary and high schools participated in this study. All teachers declared that they integrate ICTs as part of their curriculum. The academic degrees and seniority of the teachers is detailed below (all the names were changed).

Efrat – has a Bachelor's degree in Science Education and 17 years of teaching experience.

Igor – has a Master's degree in Physics Education and 18 years of teaching experience.

Moran – has a Bachelor's degree in Biology, a Master's degree in Science Education and 29 years of teaching experience.

Rachel – has a Bachelor's degree in Science Education and 9 years of teaching experience.

Rina – has a Bachelor's degree in Physics and Chemistry Education and 27 years of teaching experience.

Shany – has a Bachelor's degree in Biology, a Master's degree in Educational Technology and 17 years of teaching experience.

In this study, we applied the qualitative methodology, using the descriptive-interpretive approach (Denzin & Lincoln, 2005). This approach centers on the way in which people make sense of their subjective reality and attach meaning to it. Rooted in philosophy and social sciences, the descriptive-interpretive approach to data analysis explores the world of individual people within the context of their life. It centers on understanding human experiences, perceptions, behavior, and goals.

In order to establish research trustworthiness, we applied two types of triangulations: investigator and methodological triangulations (Denzin & Lincoln, 2005). In our study, three researchers were involved in data analysis and interpretation (investigator triangulation) and three research tools were used to gather data (methodological triangulation). The research tools were semi-structured in-depth interviews, non-participatory classroom observations, and an aptness matrix that examined the suitability between the teachers' roles and their teaching strategies. The combination of the three research tools was applied to allow different prospective of ICT usage and to deepen the researchers' understanding about ICT assimilation in the science classrooms. The research tools are described in the following sections.

Semi-structured in-depth interviews were directed towards understanding the teachers' perceptions of their teaching roles while integrating ICT, as well as identifying the teaching strategies being used. The relatively open nature of the interview permitted the researchers and the interviewed teachers to build a relationship of mutual trust. Each teacher was interviewed twice: a preliminary interview at the beginning of the academic year when the researchers entered the research field (i.e. school classrooms), and a repeated interview at the end of the academic year. The first interview started with getting acquainted with the teacher and establishing good relationship and trust. We documented the teacher's demographic, personal, and professional data (i.e. gender, sector, teaching experience, etc.). All interviewees were asked two main questions:

1. In recent years there has been substantial development in ICT and their integration in teaching and learning. In what way did this influence on your role as a teacher?

2. The literature details various teaching strategies that enhance meaningful learning. What strategies do you use when integrating ICT in your lessons? Why?

In the repeated interview, the same questions were asked, but with relation to the lessons that were observed by the researcher. This was done in order to get into details and understand the teacher's roles and strategies in depth and in context. The interviews were recorded on tape and transcribed with strict preservation of the interviewees' responses.

Observations were designed to permit methodical recording of events in the classroom, focusing on the teacher's behavior and the discussions between the teacher and the students during ICT activities. During these observations, the researchers acted as external observers – they sat in the classrooms and did not take part in the teaching and learning processes. The units of observation, specified in terms of time and space, were ICT-integrated science lessons. The observations, documented in a researcher diary, focused on the content taught in the lesson, the technology and software used, the teacher's role, the teaching methods, and the learning tasks. Four ICT-integrated lessons were observed for each teacher, giving a total of twenty-four observations.

Aptness matrix was developed to examine the aptness (in terms of suitability) between the teachers' roles and the teaching strategies they use while integrating ICT. The values displayed in each square of the matrix expresses the level of aptness between teaching strategy and teacher's role. The teaching strategies in the matrix are organized in an ascending hierarchy (displayed from top to bottom): from strategies that enhance concrete thinking – *visualization*, to strategies that enhance abstract thinking– *reflection*. Similarly, teachers' roles are displayed in the matrix in an ascending hierarchy (displayed from left to right): from *guides* – who advance students to implement the goals set at the beginning of the lessons, to *innovators* - who try out new and creative

ways of teaching. In the aptness matrix, teachers who frequently filled a role while using a certain teaching strategy received 2 points. Those who seldom filled a role while using a certain teaching strategy received only 1 point. Those who did not fill a role and did not use a teaching strategy received 0 points. An example of an aptness matrix is presented in Table 2 in the Findings section.

All the collected data were taped and documented in researchers' diaries. The data were read, re-read, and gradually analyzed from a descriptive-interpretive perspective (Denzin & Lincoln, 2005). First, the data were processed and analyzed, listing teachers' assertions and behavior. Then, categories were generated to determine the meanings of and relationships between concepts. Finally, categories were produced by three experts in science education, with a full consent. The categories are presented in the Findings section.

Findings

This section includes three subsections, corresponding to the three research questions. The first describes the science teachers' perceptions of their roles while integrating ICT in their lessons. The second discusses the teaching strategies that teachers apply while using ICT. The third attempts to characterize the aptness between the teachers' roles and their teaching strategies.

The interviews and the observations revealed that the teachers made use of a variety of software and internet systems, such as:

Argunaut – a software that supports online dialogs, enabling synchronous or non-synchronous discussions on the Internet (www.argunaut.org).

Clickit3 – a content management system designed by the ORT Israel network (clickit3.ort.org.il).

Interlect – a learning site offering courses constructed according to the Israel Ministry of Education curriculum in various subjects, such as physics (www.interlect.co.il).

V-scope – a three-dimensional multi-body motion tracing system designed for physics teaching (Ronen & Lipman, 1991).

Wiki – a Website that enables quick and simple construction of websites and knowledge sharing (www.wikimedia.org).

In addition, the teachers used Microsoft Office software, such as Word, PPT and Excel, as well as Internet search engines, such as: Google, Yahoo and Microsoft Bing. The software, the teacher using it, the learning subject, and the students' grade are detailed in Table 1.

Table 1: The software used by the teachers while integrating ICT into their instruction

GRADE	LEARNING SUBJECT	TEACHER	SOFTWARE
10	General sciences	Rachel	*Argonaut*
9-12	Physics, Biology, and General sciences	Rachel, Efrat, Moran and Igor	*Clickit3*
9-12	Physics	Igor	*Interlect*
9-12	Physics	Rina and Igor	*V-Scope*
9	Biology	Rachel and Efrat	*Wiki*
9-12	Physics and General sciences	All the teachers	*Microsoft Office*
9-12	Physics, Biology, and General sciences	All the teachers	*Search engines*

Teachers' Roles in ICT-Integrated Lessons

In this section we present selected examples, from the interviews, in which teachers responded to the question of how they perceive their roles as teachers in the information age. In addition, we present examples from the ICT-integrated class observations to reinforce the interview results.

The teacher as a guide to knowledge construction

Efrat, a biology teacher, used the 'Clickit3' system in activities related to the cell nucleus. Efrat saw her role as a guiding teacher, identifying students' difficulties while carrying out tasks, and solving technical problems when necessary:

> *"My role in the classroom varies, as each student needs me in a slightly different way. I guide and I direct, and if there are difficulties, I assist. Some students need guidance in order to carry out the assignment; others, that progress in their assignment, need direction towards a broader view so that they will be able to generalize when writing conclusions."* (Efrat, interview 26-7-2009)

Similar to Efrat, Igor, a physics teacher, sees his role as a guiding teacher:

> *"The students are asked to perform the laboratory activities and then to answer questions based on the material they learned…sometimes they don't understand the questions. I usually don't provide answers to the questions, but guide them towards finding the answers themselves…this helps them develop an independent approach to problem solving."* (Igor, interview, 1-9-2009)

Rachel, a Physics and Biology teacher used Clickit3 and Argonaut every second week. Class observations indicated that she was aware of students' needs and difficulties. Rachel instinctively located students that lagged behind and helped them focus on their assignment by providing them guiding instructions (Rachel, class observation 2009-1-18).

Data collected from interviews and observations in ICT-integrated classrooms indicated that there are two aspects to the teachers' view of themselves as guides. The first is *providing direction* by helping the students from a technical standpoint and by helping them concentrate on their work.

The second is *helping the students overcome difficulties* by providing support at different stages of task performance. Findings indicated that teachers as guides tend to examine the students' understanding and provide cognitive scaffolding to assist them. They also encourage them to think and ask questions in an independent manner.

The teacher as a motivator of students' learning

Shany, a biology teacher emphasized the importance of motivating learning by giving tasks relevant to the students:

> *"I encourage their motivation to study by raising issues that are interesting, practical, and relevant to their lives. I had a student who broke his arm and brought the x-ray to class. We talked about the x-rays and the difference between them and a C.T….I often hear them say 'I have to show this to my parents", and later I see that they browse various sites at home. I am glad to see that what I teach is not detached from reality."* (Shany, interview, 8-9-2009)

In Shany's classroom, the students were asked to create games, such as 'Who wants to be a Millionaire,' while developing questions and answers on the subject of air quality. The students were quite enthusiastic to look for information in relevant websites and to construct questions that were of interest to them (Shany, class observation, 20-1-2009).

Moran motivated the learning process by personally accompanying each student at each stage of their task performance. In a lesson about the digestive system, Moran approached to the students and encouraged them to make progress:

> *"I sat next to a girl who had given up on learning during the lesson. I told her we would look together at the animation…I sat with her and we went through it step by step. I asked her to explain the process out loud. This raised her motivation and encouraged her to continue studying on her own."* (Moran, interview, 20-7-2009)

With the assistance of ICT, the teachers selected or developed authentic assignments, relevant to the students' daily lives. This stimulated interest and raised students' motivation to learn. The use of ICT also freed the teachers' time to provide personal attention and to follow the students' learning as they moved through the various stages of their assignments. Thus, the teachers encouraged the students' progress on both a group and an individual level.

The teacher as a partner in the learning process

In activities on the Sea of Galilee, using Wiki website, Efrat described how she studied topics, in which she was not proficient, together with her students:

> *"Of course, I studied together with them…for example, when we learned about materials that contaminate water. The explanations we found on the website were on a very high level, so we tried to think what happens to nitrate and phosphate during the month of May, when the water is most contaminated. Why is the month of the year significant? Is there a difference between the substances? Do they influence each other? These were topics that I was not familiar with and I felt obligated to learn together with the students and to prepare a flow chart with them."* (Efrat, interview, 26-7-2009)

Shany, a biology teacher, asked her students to create educational games and to develop questions about different environmental issues. When some of the students did not know how to answer their own questions, Shany browsed with them through educational websites, learned with them about the various topics, and helped them formulate high level responses to their questions (Shany, class observation, 20-1-2009).

In an interview, Igor, a physics teacher, emphasized his partnership with his students in learning, when the topics were abstract and complex:

> "*In physics, there are complex and abstract topics in which the students have many questions. In some cases when I do not know the answer, we open the Internet and learn together about what is new in the field."* (Igor, interview, 1-9-2009)

Two instances were found in which teachers acted as their students' partners in the learning process: when the problem presented was new and complex and when the students were interested in studying a particular subject in depth, beyond the teacher's own knowledge. In both instances, the teachers and students used ICT, such as search engines and electronic encyclopedias, to gain knowledge.

The teacher as an innovator

Rachel, a biology teacher, integrated Argunaut system, a new technology for her, at the time the research was conducted:

> *"It's a tool that only few teachers use. I liked the idea behind it and I decided to use it in my classroom. The biology staff and I had seen the system only once but we were told that a delegation of educators from Colombia was arriving to Israel in order to learn how to use the software. I had only a few days to learn how to operate it."* (Rachel, interview 12-7-2009)

Shany learned to use the SMART board, a new technology for her, at the time the research was conducted:

> *"When I began working in the school, I was told: 'listen, we have a new technology called SMART board, maybe you'll remove the nylon wrapping and learn how to use it?' At the beginning I was afraid, because it was the first time that I used the SMART board. I almost forgot to use the special marker. Today I'm happy that I was able to learn to use a new technology."* (Shany, interview, 8-9-2009)

Analysis of interviews with Shany shows that ICT helped her to implement inquiry-based learning, which she sees as a new way for teaching:

> *"The students weren't familiar with inquiry-based learning. While using search engines and reading materials in educational websites, they also learned the principles of asking questions, searching for information, making assumptions, and writing a paper."* (Shany, interview, 8-9-2009)

The results show that teachers who used ICT felt like innovators from two standpoints: the integration of innovative technologies and the integration of new teaching strategies. Some of the teachers stated that they were looking for new technologies and new ways of teaching; others stated that they will continue with the same teaching methods they were used to. The following section presents the teaching strategies used in the ICT-integrated classrooms that we observed.

Teaching Strategies in ICT-Integrated Lessons

Analysis of the interviews and observations suggested that while integrating ICT the teachers used mainly four teaching strategies for encouraging in-depth, meaningful learning: visualization, problem-solving, inquiry, and reflection. In some lessons the learning was cooperative and in others it was individual and independent.

Visualization strategy

Moran, a biology teacher, integrated computers in her classroom for the purpose of visualization:

> *"My goal is that students will pass their matriculation examination in Biology. By using computerized animations, biological principles can be illustrated and better understood, without the students needing to learn concepts by heart."* (Moran, interview, 20-7-2009)

In a lesson on genetics, Efrat presented an animated version of an experiment that had been performed by biologists on a cell nucleus. The students were asked to watch the animation and to fill out a worksheet (Efrat, class observation, 18-1-2009).

Igor integrated demonstrations of computerized laboratories in a physics lesson:

> "*When I wanted to teach the law of conservation of linear momentum, I asked the students to watch a simulation that presented a laboratory experiments, and to answer the questions that appear on the website... It was much easier to understand than if I explained the law by just writing equations on the board."* (Igor, interview, 1-9-2009)

Rachel taught about electric power plants while her students watched a computerized animation on the process of producing energy:

> *"While watching short animated movies, my students learned about different kinds of power plants, how they work, and how energy is produced. Some of the animations were mandatory for all students, and others were optional, only for those who finished the basics and were able to proceed."* (Rachel, interview, 12-7-2009)

Interviews and observations indicated that the use of visualization, in the form of web-based animations and/or simulations, assisted teachers in simplifying abstract concepts. It also helped the students understand complex scientific principles and processes that cannot be observed or demonstrated in the classroom.

Problem-solving strategy

Efrat presented her students with a problem entitled "A world without bacteria." With the assistance of Clickit3 software, the students were asked to analyze the situation and provide several solutions:

> *"I presented my students with a hypothetic situation: let's say we had a bomb that could destroy all the microorganisms in one day. Let's see, if it would really be so great... This problem doesn't have a single solution and therefore each group had to examine the advantages and disadvantages of microorganisms in different areas such as agriculture, food industry, or health. The students were asked to read an online article and to relate to different aspects of the problem."* (Efrat, interview, 26-7-2009)

Shany also used ICT as a source of information to solve a problem:

> "*I presented a certain medical problem that calls for the use of x-ray, C.T. or MRI. The students were asked to look for information on the Internet and decide which type of medical imaging is best to use based on health risks, levels of radiation, availability of the instrument and other criteria."* (Shany, interview, 8-9-2009)

Igor implemented problem-based learning while using a website that simulated a computerized laboratory. The students were given an open problem about momentum conservation and were asked to solve it (Researcher Dairy, 1-1-2009).

The teachers used ICT to present their students with complex problems that usually included a number of variables and a number of possible paths for solution. In some lessons, the students were asked to perform laboratory activities or watch simulations in order to reach a solution. The problem-solving strategy was carried out for the most part in groups but sometimes individually, according to the teacher's decision and the number of available computers.

Inquiry strategy

Efrat described the inquiry-based activities that her 9th grade students carried out using Wiki technology:

> *"...we presented the students with a real phenomenon taking place in the Sea of Galilee. It seems that many fish die every year in May. The students had to investigate this phenomenon by planning an experiment and examining whether the factor they chose was that which was causing the mortality…To answer the scientific questions, we referred to professional researchers with the help of an Internet learning site."* (Efrat, interview, 26-7-2009)

Shany implemented inquiry-based learning by asking her students to investigate a hereditary disease with the assistance of information and pictures from special websites:

> "*I decided to give them an assignment in the field of genetics and asked them to investigate the subject of genetics and hereditary disease, each group of students received a different disease."* (Shany, interview 8-9-2009)

Rachel described inquiry-based learning activities on power plants that she presented in class with the help of Clickit3 technology:

> "*They hadn't learned about power plants before and they also didn't know how electricity was produced. I directed them to information sources so they could investigate the different types of power stations and ways to produce electricity."* (Rachel, interview, 12-7-2009)

While applying the inquiry strategy, the teachers used ICT to present their students with a real-life situation that needed to be investigated. They provided students with activities that develop scientific thinking and the understanding of how scientists learn about the world.

Reflective strategy

Over the course of this study, Shany was the only teacher, among the six participants, who applied the reflective strategy. Shany reported the use of reflection in activities using a knowledge sharing software during biology lessons:

> *"I believe that reflection and meta-cognition are very important for the learning process. My students use these processes during online discussions or when working on an assignment. For example, if they can't solve a problem or answer a question, I ask them to write me why they think they couldn't answer and what data is missing."* (Shany, interview, 8-9-2009)

Another example Shany gave:

> *"I asked the students to write what they were going to do in their assignment, why, how, and when. After completing the assignment they were asked to check what they succeeded in doing, whether they were satisfied and how they could have improved their performance."* (Shany, interview, 8-9-2009)

Aptness between Teachers' Roles and Teaching Strategies

Based on the interviews and class observations, an aptness matrix was developed for each teacher with the aim of examining the suitability between the teacher's role perception and her/his teaching strategies while integrating ICT. In this section we chose to present Shany's aptness matrix (Table 2) since she is an example of a teacher that made much progress in the use of ICT-integrated teaching.

Table 2: Shany's aptness matrix

ROLE						
Total score for teaching strategy	Innovator	Partner	Motivator	Guide		STRATEGY
8	2	2	2	2	Visualization	
8	2	2	2	2	Problem-Solving	
8	2	2	2	2	Inquiry	
6	2	0	2	2	Reflection	
30	**8**	**6**	**8**	**8**	Total score for teacher's role	

Shany's aptness matrix, presented in Table 2, shows that she skillfully assimilated all four roles while applying all four teaching strategies, except for acting as a partner while applying reflective strategies. All together, Shany received 30 points, out of the 32 possible points. This shows that Shany is able to efficiently use new ICT-based learning environments, apply various constructivist strategies, and adopt innovations to improve her students' learning.

The analysis of the aptness matrices of the other participants indicated that Rachel received 21 points, Efrat 19 points, Igor 17 points, Rina 14 points, and Moran only 5 points. Findings indicated that most of the teachers perceived their roles as being guides and motivators of the learning processes, while using teaching strategies that encouraged visualization and problem-solving. This means that there is a high level of aptness between these teaching roles and strategies. Contrary to that, low aptness levels were found between teachers' roles as partners and innovators and strategies such as inquiry and reflective learning.

In order to determine the teachers' stages of ICT assimilation, according to ACOT model (Sandholtz et al., 1997), three experts in advanced technologies examined the aptness matrix of each teacher separately. Full agreement among the researchers was reached during discussions that were based on the data collected in the interviews and the observations. Table 3 shows that Shany received the highest score in the aptness matrix and that she is also in the highest stage of the ACOT model – the *Invention* stage. Conversely, Moran received the lowest score in the aptness matrix and she is also in the lowest stage of the ACOT model – the Entry stage. Efrat, Igor, and Rina are in the Adaptation stage, whereas Rachel is in the Appropriation stage. These finding suggest that insofar, as teachers grasp the wider aspects of their roles and use a greater variety of teaching strategies, they assimilate technologies in learning and teaching in a more logical and creative way that is likely to facilitate constructivist learning.

Table 3: The teachers' aptness matrix score and the ACOT model stage

ACOT MODEL STAGE	APTNESS MATRIX SCORE	TEACHER'S NAME
Stage 1 - Entry	0-6	Moran
Stage 2 - Adoption	7-13	-
Stage 3- Adaptation	14-20	Efrat, Igor, Rina
Stage 4 - Appropriation	21-27	Rachel
Stage 5- Invention	28-32	Shany

Summary

The findings of the current study indicated that the teachers viewed themselves in the roles of guides and motivators of the learning processes. Only a few of them viewed their roles as learning partners or as innovators. All the teachers that participated in this study used strategies that encouraged visualization-based learning, and most used problem-solving based learning. Only a few used inquiry-based learning and only one teacher used reflective learning, even though educational researchers recommend its implementation (Henderson et al., 2004). It appears that this approach has not yet been assimilated enough in ICT-integrated lessons (Eyler & Giles, 1999; Henderson et al., 2004).

During the course of the study an aptness matrix was developed as a tool to examine the suitability between the teachers' role perceptions and the teaching strategies they used. The teacher's roles were represented in the matrix in an ascending order: from guide, who advances his or her students to carry out objectives set at the beginning of the lesson, to innovator, who experiments with new teaching methods and technologies. Similarly, the teaching strategies were also arranged in the matrix in an ascending order: from a concrete thinking level – visualization, up to an abstract thinking level – reflective learning, defined in the literature as a higher order thinking skill (Granville & Dision, 2005).

The research findings show that the aptness matrix scores can be parallel to the ACOT model of assimilation of new technologies (Sandholtz et al., 1997). Moran, in spite of having 29 years of teaching experience, was at the entry stage with regard to the assimilation of ICT in instruction. Three of the teachers that participated in the study, Rina with 27 years of teaching experience, Igor with 18 years, and Efrat with 17 years, were at the adaptation stage. Rachel, with 9 years of teaching experience, was at the appropriation stage, and Shany with 17 years of experience was at the invention stage. No correlation was indicated between teachers' ages, years of teaching experience, and the stage of assimilation of ICT.

The aptness matrix developed in our study consists of four teachers' roles and four learning strategies, chosen from a wide range of roles and strategies in the literature. It was designed in a way that allows researchers and educators to add or delete roles and strategies in relation to the examined learning environment. In line with the claim that emerging technologies should be used for enhancing constructivist teaching and learning (Rambe & Ng'ambi, 2011), different types of aptness matrixes can be developed, given that the teacher roles and teaching strategies support active and meaningful learning. Indeed, recent studies show that the integration of Web 2.0 tools en-

hances constructivist learning environment and that emerging technologies challenge, ground, and ultimately, enhances students' understandings (Barak, Herscovitz, Kaberman, & Dori, 2009; Rambe & Ng'ambi, 2011).

The matrix can be used as a formative assessment tool for teachers that are in various stages of ICT integration. Identification of strengths and weaknesses is likely to raise science teachers' awareness of their own teaching methods and roles in the classroom and to result in their reinforcing the constructivist approach while integrating ICT. The modern science teacher is a mixture of teaching roles and teaching strategies, and no one strategy is as powerful as utilizing a combined strategies approach (Wise, 1996). The teacher should judiciously select from a variety of strategies and roles those which will most effectively enable his learners to develop meaningful learning while integrating ICT.

Research Limitations and Strength

The limitations of our study are in line with the limitations of qualitative research. The research findings are dependent on the individual skills of the researcher and might have been influenced by personal biases and world-views. The researcher's presence in the classrooms during data gathering might have affected teachers' and students' behavior. The small sample of participants (six teachers) might raise two problems. The first problem relate to issues of anonymity and confidentiality when presenting the findings. Because of the small sample and the specific ICT each teacher used, we were concerned about possible breach of anonymity and that the teachers might feel exposed. The second problem relates to the issue of external validity. Qualitative studies that consist of only few participants do not allow the generalization of results and conclusions. In addition, similar to all qualitative studies, the analysis and interpretation of massive data collected in the observations and interviews were time consuming. In order to overcome the limitations detailed above, and in order to establish research trustworthiness, we applied two types of triangulations: investigator and methodological triangulations (Denzin & Lincoln, 2005), detailed in the Research Method section. In addition, since all the teachers were leaders in their schools, and had confidence in their work, they expressed no concern about being exposed.

The strength of our study lies in that it explored teachers' roles and teaching strategies in depth. We examined teachers in their natural working environment (schools and classrooms), and every interview was related to a class observation and vice versa. The data was based on teachers' experience, perceptions, and behavior, which is more powerful and compelling using quantitative analysis. Although our findings cannot be generalized to a larger population, it can however be transferable to other settings. The aptness matrix, for example, can be used in further studies as a formative assessment and in teachers' training as a reflective tool.

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