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ICT in science education: A new language of meaningful learning or a visual gimmick? Teacher perceptions of ICT's strengths and weaknesses

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ABSTRACT

The current tendency to integrate Information and Communication Technology (ICT) into teaching challenges teachers to both develop and convey Technological Pedagogical Knowledge (TPK). This study examines the extent to which science teachers who have integrated ICT into their practice really demonstrate awareness of the aspects of meaningful learning and TPK and how these manifest in their ICT implementations [Visualization of Science Concepts (VSC), promotion of Informational Searching Skills (ISS), Real-Life Problem Solving (RLPS), and Collaborative Knowledge Construction (CKC)]. The findings indicate that most teachers' perceptions of ICT implementations mainly concentrate on basic and traditional needs in primary science education: VSC and RLPS only. The findings don't indicate awareness of the importance of advanced implementations: ISS and CKC. The challenge of explicitly emphasizing the relationship between basic and advanced ICT implementations and the aspects of meaningful learning definitely exists. Both teacher preparation and cultural views regarding learning and instructional processes in science education contribute to successful outcomes with regard to science education.

Keywords: Science education, ICT, meaningful learning, TPK.

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INTRODUCTION

Information and Communication Technology (ICT) offers a variety of opportunities for meaningful learning that promotes advanced technological capabilities (Keengwe and Onchwari, 2012). The effort to realize the potential of ICT impels the discussion regarding the optimal methods for integrating it into different instructional paradigms in science education so as to promote high-order thinking skills: managing, analyzing, critiquing, and cross-referencing (Madhuti et al., 2012; Madtes and Britt, 2013). The current study has three main goals: (a) recognition of science teachers' perceptions regarding the strengths and weaknesses of ICT as a new language of meaningful learning; (b) investigation of the relationship between science teachers' Technological Pedagogical Knowledge (TPK) and the main ICT implementations [Visualization of Science Concepts (VSC), Information Searching Skills (ISS), Real-Life Problem Solving (RLPS), and Collaborative Knowledge Construction (CKC)].

Science teachers' TPK

Technological Pedagogical Knowledge (TPK) is defined as the integrated knowledge of educational technologies and their potential for fulfilling pedagogical needs (Angeli and Valanides, 2009). The main perception of TPK is that educational technology is not just a vehicle for visualization of ideas and delivery of information, but rather a tool for the acquisition of meaningful learning skills (e.g., engagement in learning experiences, knowledge construction, problem solving, and use of informational resources) (Jacobson and Kozma, 2012; Kramarski and Michalsky, 2010). The complexity of this perception challenges researchers to establish a connection between the TPK theoretical definition and its practical applications, relating to various skills (Graham, 2011).

In the current study, TPK refers to a means of encouraging the following abilities in teachers: (a) matching technological implementations to pedagogical purposes, (b) reaping technological benefit from understanding science concepts and their use in knowledge structuring, (c) promoting meaningful learning and high-order thinking skills through ICT (Madhuri et al., 2012; Guzey and Roehrig, 2009).

TPK variously influences teachers' pedagogical ability. A high level of TPK can encourage and create active learning experiences and encourage student engagement in construction of new knowledge (Mishra et al., 2010). TPK can promote teachers' ability to convey relevant messages to students, not only at domain specific levels, but in the teaching methods and the technological language used (Chai et al., 2011). Moreover, in the current era teachers cope with various challenges that require that they show technological and pedagogical literacy not only in the content they teach (Pedagogical Content Knowledge), but also in their insight into the accompanying learning processes: the handling of student difficulties and misconceptions and the nurturing of student understanding by placing high valuation on what is taught. These insights are the foundation of a learning environment that not only has educational value (Keengwe and Onchwari, 2012; Fink, 2013), but also responds to the needs and difficulties of students. Three aspects of meaningful learning: engagement in the learning experience, emphasis on the relevance of learning, and promotion of high-order thinking skills will be examined in this study.

TPK and meaningful learning

Recent studies (Guzey and Roehrig, 2009; Tasar and Timur, 2010; Graham, 2011) indicate that in general science teachers find that integration of ICT into science education makes a significant contribution to meaningful learning. Yet science teachers reveal that they make little use of technology for this purpose and mostly use it to preserve old teaching methods and paradigms (e.g. presentation of information, visualization of concepts, and delivery of instruction). Very little usage of technology focuses on the development of high-order thinking skills or the engagement of students in learning processes and experiences (McCrory, 2008; Madhuri, 2012). This situation has both short- and long-term implications for meaningful learning (Chai et al., 2011).

This situation challenges the educational system to prepare students for the skills demanded in the 21st century. The "old-fashioned" teaching paradigm places students in a passive role and does not sufficiently involve them in their own education (Armbruster et al., 2009). However, meaningful learning obtained through integrating ICT into science education requires a change in science teachers' approach with regard to this issue.

Research goals

The goal of the current research is to examine teacher perceptions of the strengths and weaknesses of integrating ICT implementations into instruction. This research investigates the following:

1. What are teachers' perceptions of the *strengths* of integrating ICT into science education? How are major ICT implementations related to the aspects of meaningful learning?
2. What are teachers' perceptions of the *weaknesses* of integrating ICT into science education? What are the pedagogical considerations behind teachers' approaches and which ICT implementations are seen as ineffective in terms of meaningful learning?

METHODOLOGY

This study is based on a qualitative methodology that uses the descriptive-interpretive approach with data obtained through personal interviews which are then analyzed. This type of approach allows the researcher to understand participants' perceptions, positions, and actions (Denzin and Linkcoln, 2005). In the present study, this methodology is used to examine the subjective perceptions of the participating teachers who have documented the integration of ICT into their teaching and who have allowed the researcher to interpret their own perceptions of their implementations and their impressions of ICT as a learning solution.

The participants

Twelve elementary school science and technology teachers from a small technologically advanced country in the Middle East took part in this study. These teachers hold ICT implementations in positive regard as instructional tools and profess a high level of TPK. The participants' ages range from 24 to 45 years, with teaching experience ranging from 4 to 18 years. Most of the participants (11 out of 12) were women due to the small number of men who teach science and technology.

Instruments

The research questions were constructed according to Sabar Ben Yehoshua's model (Eilon, 2010), of a semi-structured interview. The questionnaire while directing teachers to refer to clearly established points and questions written in advance of the interview also provides an opportunity for conversations to develop in other directions. This allows participants to express their positions on the subject under examination and to relate it to their own experience.

The interview consists of 15 open questions prepared for this specific study. Respondents were asked to explain their views on the integration of ICT into science education and to give examples of ICT implementations. The interview consists of three parts: questions to reveal the frequency of ICT use and the manner in which it is used, an examination of the teacher's methods of ICT use as a learning solution, and teachers' opinions regarding the relationship between ICT implementations in science education and the aspects of meaningful learning mentioned above. Teachers were asked to give examples of their preference for use of ICT over frontal teaching without ICT, as well as to express their personal perceptions of the strengths and weakness of ICT implementations (Appendix).

The interview allows for understanding of the experience of science teachers who integrate ICT into their work. The stages of documenting the interviews began with clarifying and defining the objectives of the research and constructing the accompanying questions that would allow participants to share and demonstrate their experience with use of ICT in instruction. Beginning with general questions, the survey's more focused questions enabled validation of the findings. The order of questions was identical for all participants.

Data analysis

Analysis of the study data began with breaking down the information into its components and organizing it into new constructs (Eilon, 2010). After intensive reading of all the interviews, the teachers' responses were categorized according to their statements regarding various ICT implementations and their perceptions of the strengths and weaknesses of such implementations. The next stage concerned the relationships that developed between the categories created and the aspects of meaningful learning. Data processing was performed according to the Denzin and Lincoln (2005) method wherein the researcher interprets comments from the field while trying to understand its implications. The final stage of data analysis consisted of mapping ICT implementations with regard to aspects of meaningful learning (Figure 1).

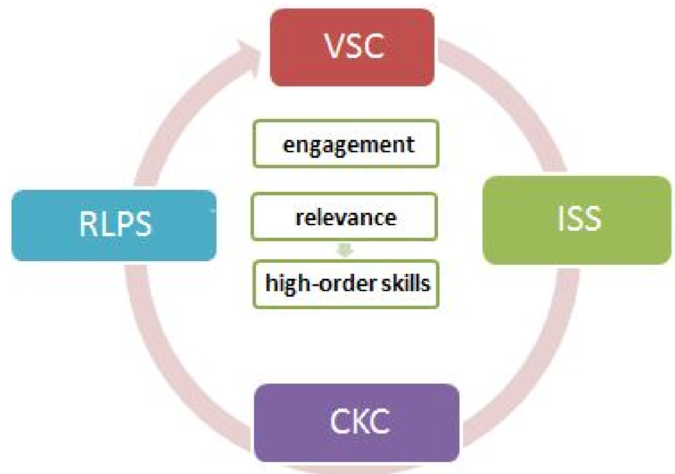

Figure 1. Model mapping ICT implementations (VSC, ISS, RLPS, CKC) with regard to aspects of meaningful learning (high-order skills, engagement in learning experience, emphasis on the relevance of learning). VSC: Visualization of Science Concepts; ISS: Informational Searching Skills, RLPS: Real-Life Problem Solving; CKC: Collaborative Knowledge Construction.

RESULTS

One outstanding datum among the study's findings is that although the sample only included those teachers who defined themselves as experts in TPK and ICT, their perceptions indicate that their basic technological implementations in the classroom were primarily directed toward concrete illustrations using films and simulations. Although there is evidence of active instruction, use of learning strategies directed toward independent learning was barely evident. This finding was reflected in the strengths and weaknesses of ICT implementations (VSC, ISS, RLPS, CKC) noted by the interviewees. In order to keep on the respondents' privacy, were used the fictitious names.

Strengths of ICT for visualization of science concepts (VSC)

Many teachers use ICT as a didactic solution for visualization of science concepts. It is the preferred way to cope with student misconceptions of scientific principles and processes. Teachers tend to employ ICT to demonstrate science experiments that cannot be performed in the school lab and as such it develops high-order thinking skills and cognitive value. According to Nina, a middle-school teacher:

> In frontal teaching, it is difficult to describe processes. The computer helps the teacher inasmuch as there is no need to explain in words how a red blood cell incorporates iron. I simply show a simulation and that does the job.

Lucy also describes the processes of illustration as a means for internalizing material:

> The use of technology brings phenomena closer to the learner and explains processes in a clearer manner. Graphic representation of processes and phenomena facilitate

> internalization by the learners.

Half the participants in the study indicated that use of ICT reinforces student concentration and facilitates better use of learning skills. For example, Sofia holds:

> When I use ICT in instruction, I don’t have to 'work too hard' to attract student attention. The moment the projector is turned on; all eyes are immediately on me.

Many teachers feel that ICT serves as an asset for understanding and assimilating material. They contend that sensory stimuli increase the ability for assimilating the matter to be learned. Leah says:

> By using the computer, the material studied is absorbed better because the children see, hear, and remember better. Sound, image, and emotion lead to long-term remembering.

Lucy adds his example of ICT's contribution to high-order thinking skills:

> Photosynthesis is very hard for children to understand. When children see a picture of the process, they don’t always understand it. When I show them a simulation, they see what happens at every stage of the process, allowing them to understand, analyze, and remember it much better.

Highlighting science concepts and processes by visualization media (e.g. interactive applets, animation, clips, and movies) is considered to be an efficient learning stimulus for promoting student engagement in learning experiences. The ability to add variety to the traditional science lesson using ICT is perceived as positive. According to Dana:

> We have introduced more life into learning, more possibilities. While the material studied is the same material, the ability for variation has increased immensely. I easily integrate a film, a video clip, a game, a text, ICT tasks, etc.

Other teachers also say that they often demonstrate experiments virtually using java applets, movies, and animations instead of conducting "live" experiments in class. Dana takes note of the relevance of ICT's potential:

> I prefer using science animations during the lesson because the children are automatically attracted by the computer; the computer speaks to today’s children. When we don't integrate ICT into teaching, we are not talking with the children in the language they’re used to and have been exposed to. In order to interest the children, encourage their motivation to learn and their involvement with the subject, there is a need to speak in a language familiar to children.

Strengths of ICT for information searching skills (ISS)

Some teachers’ claim that based on their experience, students' high-order thinking skills significantly improve in an environment that incorporates information searching tasks. In Nina's words:

> In my opinion, information searching with ICT is really meaningful for students. In ICT the student receives information and understands it more easily. Because his understanding is greater, the learning is more meaningful.

According to Elison, ISS-based activities are particularly useful due to their promotion of scientific thinking and their highlighting of the relevance of the learning.

> Information is much more available. While teaching a subject, the teacher can access available information resources, pictures, and articles and show them in real time, making them as relevant as possible, a tsunami, an earthquake, etc. The students themselves can also find available and relevant information much more easily.

The strength of ICT for real-life problem solving (RLPS)

Several participants emphasize the engagement aspect of learning with ICT. Rebecca points out that when she gives her students a real-life task she makes efforts to design an assignment in which students interact with one other. She says:

> I am talking to you from my experience in the classroom. When there is a lesson with laptops and students have a task to perform, the children are happy to work. They ask me to have computers at every lesson.

The structuring of basic scientific knowledge using real-life problems is the strength of ICT according to Sara:

> I use ICT when I want to grab students' attention. When starting a new topic, for example, electrical energy, I show the students a video about a power outage during a soccer match at Teddy Stadium. From there I pose a real-life question or problem and discuss it. Only then do

> I begin to teach the subject.

Many other teachers mentioned that real-life problem solving in an ICT environment assists them in dealing with classroom heterogeneity as it allows students to perform learning tasks at their own rate. The interviewees testified that ICT helps students with low learning capabilities to understand science topics in depth, assists them in being involved in the learning process, and allows them to be engaged in a friendlier, more comfortable learning environment. For example, Rina said:

> When I give ICT tasks, I essentially allow each student to work at a task suited to his level, ability, and individual pace. That's something I could never do in a frontal lesson with an entire class.

Regarding ICT's potential for developing high-order thinking skills, divisions in opinion were heard. Eva, a middle school teacher explains how she promotes high-order thinking skills through ICT:

> This is expressed when the student is asked to organize information in a graphic manner, to draw conclusions or represent information in a chart.

However, Rebecca has reservations:

> I think that use of ICT has a possibility for stimulating high-order thinking skills, but this depends on the way it is used. If a teacher takes an ICT activity, develops suitable questions to go along with it and gives suitable direction, it certainly can be a tool requiring high cognitive skills.

A summary of teachers' perceptions regarding the strengths of ICT implementations in science education with respect to aspects of meaningful learning is presented in Figure 2.

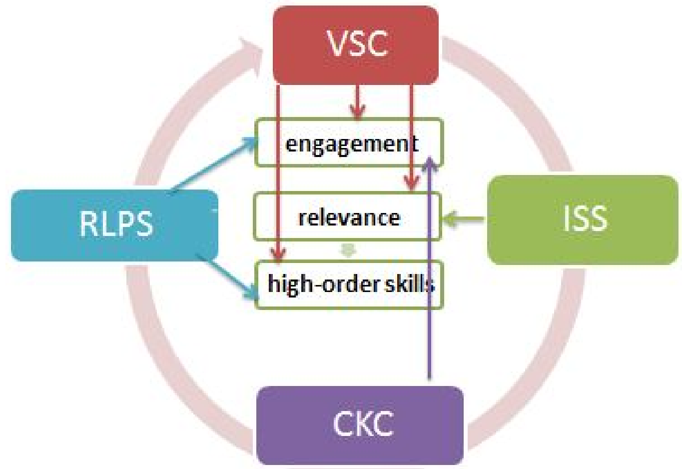

Figure 2. Model mapping the strengths of ICT implementations (VSC, ISS, RLPS, CKC) with respect to the aspects of meaningful learning (high-order thinking skills, engagement in learning experiences, emphasis on the relevance of learning). VSC: Visualization of Science Concepts; ISS: Informational Searching Skills, RLPS: Real-Life Problem Solving; CKC: Collaborative Knowledge Construction.

Weaknesses of ICT for visualization of science concepts

Regarding the weaknesses of ICT, differences of opinion were found. Lea claims that ICT implementations actually worsen engagement in the learning process and do not really assist in the development of high-order thinking skills in science. In Lea's opinion, ICT does not fit the needs of strong students. She also claims that increased implementation of ICT for visualization of science concepts creates unnecessary dependency upon visual "gimmicks" and damages students' ability to concentrate in traditional frontal lessons that do not have ICT implementations. When those visual stimulations are absent, students become bored and this in turn hurts the outcome of the lesson.

Several study participants claim that not only does ICT damage student imagination and creative thinking, but it also reduces students' need to think and to imagine. According to Lea, the visual features of ICT reduce high-order thinking in science:

> ICT use does not provide for the development of higher-order thinking skills. It was initially designed for low-level students who needed visual interest in order to illustrate processes. It turns out that because of the weak students, the strong students enjoy the visual quality and receive information that has already been chewed and is ready to be swallowed.

Sima points to another aspect of this argument:

> It's not magic. In order for the learning to be meaningful, students have to work and internalize and there are teachers whose use of ICT doesn't activate anything beyond students' visual sense.

A summary of teachers' perceptions regarding weakness of ICT implementations with regard to aspects of meaningful learning in science education are represented in Figure 3.

The findings of this study reveal that the strengths of ICT are mentioned in conjunction with all four implementations: visualization of science concepts (VSC),

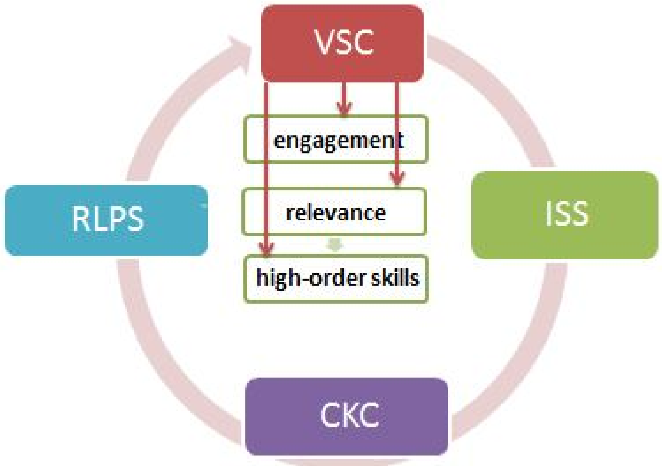

Figure 3. Model mapping the weaknesses of ICT implementations (VSC, ISS, RLPS, CKC) with regard to the aspects of meaningful learning (high-order thinking skills, engagement in the learning experience, emphasis on the relevance of learning). VSC: Visualization of Science Concepts; ISS: Informational Searching Skills, RLPS: Real-Life Problem Solving; CKC: Collaborative Knowledge Construction.

information searching skills (ISS), real-life problem solving (RLPS), and collaborative knowledge construction (CKC). In each of these four implementations, many advantages were mentioned in relation to meaningful learning, such as the creation of an empowering learning environment, promotion of high-order thinking skills, and emphasis on the relevance of science education. Teachers claim that ICT aids enable students to learn at their own rate which is a relief for weaker students. Strong students also experience the usefulness of available information in science domains and improve their searching skills and high-order thinking skills.

The weaknesses of ICT that were mentioned relate only to VSC implementations and consist of discouragement of imagination and reduction of cognitive value, damage to student engagement and personal experience of the subject to the extent that it reduces the relevance of science education for stronger students.

DISCUSSION AND CONCLUSIONS

The main propose of this study was to investigate teacher perceptions of the strengths and weaknesses of ICT implementations with respect to meaningful learning. The main consideration behind the selection of subjects was an assumption that experienced in ICT and with a high level of TPK would naturally describe their teaching experience within the framework of meaningful learning and various ICT implementations. However, it was discovered that participants related to only a small part of the repertoire of ICT implementations (e.g. VSC and RLPS). In these two ICT implementations, teachers' claims did indicate a high level of TPK based upon the aspects of meaningful learning as their well-substantiated arguments regarding these aspects show. Indeed their remarks regarding ICT implementations touched upon the all the aspects of meaningful learning. Only a few teachers used other ICT implementations, such as ISS or CKC for their pedagogic needs. The teachers mentioned only a small number of the aspects of meaningful learning, e.g. ICT assists in promoting high-order thinking skills and encourages student engagement in the learning experience. Very few teachers placed any emphasis on the relevance of learning with regard to ISS and CKC (Figure 2).

The teachers who noted the weaknesses in ICT visual implementations (Figure 3) reinforce the conclusions of Vavra et al. (2011) who maintains that using ICT for visual purposes does not promote meaningful learning as opposed to the ICT implementations that encourage student interaction and cooperative knowledge construction (Fullan nda Langworthy, 2014).

The findings of this research shed light on the lack of explicit teacher awareness concerning the aspects of meaningful learning and the use of ICT implementations to meet these needs, within a specific group of science teachers. Their perceptions concerning strengths and the weakness of ICT implementations mostly concentrated on the basic traditional needs of primary science education: VCC and RLPS. The participants did not show awareness of the importance of advanced implementations: ISS or CKC. The challenge of making multi-focal ICT implementations that meet both basic and advanced needs for meaningful learning exists and it depends upon teacher preparation (Xu et al., 2011) and the teachers' cultural views regarding learning and instruction processes in science education (Fink, 2013; Keengwe and Onchwari, 2012; Peled and Sarid, 2010).

It should be noted that the conclusions of this study are based on data obtained from only twelve science teachers. Hence, it is not possible to claim that the findings are valid for the entire population of science teachers. That said, this study may indicate that only limited pedagogical change has occurred in science education since the introduction of ICT as a smart tool. To validate this study’s results, the number of participants in the study should be increased. Furthermore, it is recommended to return to this group of teachers to examine whether they had received any preparation for a change in the teacher’s role through the use of ICT and what these teachers' willingness to be instrumental in this pedagogical change might be. It is worth examining the teachers who did feel the need for pedagogical change with regard to perceptions of their instruction and what would motivate them to make a change in their instructional pedagogy. In addition, it is recommended to re-examine the content of in-service teacher training in order to explicitly emphasize the relationship between basic and advanced ICT implementations and the aspects of meaningful learning. This study may indicate a need for a change in emphasis in ICT course design so as to sharpen the focus on ICT as a meaningful learning language instead of just "becoming familiar with available ICT tools" which has become a popular concept in teacher training.

We believe that this may advance considerations about a revised approach to ICT in the education system that could empower teachers to become independent ICT-oriented leaders who have developed the ability to be continuous learners in possession of the ability to internally navigate and direct their learning processes. People who construct knowledge and use high-order thinking skills and learning strategies are precisely what characterize 21st century learners.

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Appendix: Questionnaire for teachers' semi-structured interview

Personal information: Age _____ Seniority in years ______
Elementary school teacher/Middle school teacher
Male/Female

1. Do you use ICT in your teaching?
2. Does the possibility for using it exist? Would you prefer teaching an ICT lesson instead of a lesson that isn't an ICT lesson? Explain.
3. Many teachers are aided by ICT for illustration. Are you also aided by ICT in that way? What is the extent of your use of ICT as a tool for illustration?
4. Below are statements dealing with the extent of your ICT use. Rank each statement according to your degree of agreement with it.

Statement	**Strongly Agree**	**Agree**	**Unclear to me**	**Disagree**	**Strongly Disagree**	**Comments or explanation**
I am aided by ICT technology to a great degree (3–5 lessons a week)						
I use ICT to a great degree to present films						
I use ICT to a great degree to present simulations						
I use ICT in the classroom to gather encyclopedia information during instruction						

5. Mention names of films/simulations/sources of encyclopedia information that you have used.
6. In your opinion, is there a difference between instruction prior to computerization and instruction using it? How are the differences/similarities expressed?
7. Below are statements dealing with your degree of ICT use. Rank each statement according to your degree of agreement with it.

Statement	**Strongly Agree**	**Agree**	**Unclear to me**	**Disagree**	**Strongly Disagree**	**Comments or explanation**
Integrating ICT technology can promote quality instruction to a great degree						
Integrating ICT prepares the students well for a technological world and provides them with 21st century skills						

8. Does the use of ICT create more meaningful learning in your opinion? Explain.
9. Below are statements dealing with your degree of ICT use. Rank each statement according to your degree of agreement with it.

Statement	**Strongly Agree**	**Agree**	**Unclear to me**	**Disagree**	**Strongly Disagree**	**Comments or explanation**
The use of ICT makes learning interesting for most students						
The use of ICT makes learning comprehensible for most students						
The use of ICT allows for the understanding of complex processes						
The use of ICT allows for long-term memory						
The use of ICT creates the internalization of scientific concepts						
There are students who prefer being instructed by the teacher without ICT						

10. In your opinion, does ICT replace the need for a teacher? Explain.
11. In your opinion, does the use of ICT provide for the development of higher order skills (analysis, synthesis, evaluation) more than instruction without it? How is this expressed?
12. In your opinion, does the use of ICT increase student achievements more than learning without it? Explain.
13. When you use ICT, do you abandon the frontal teaching method? Explain.
14. Does using ICT mean relinquishing traditional instruction? Are there advantages to traditional instruction that are missed by using ICT? What is your opinion?
15. Does the use of ICT during instruction cause you to change/feel the need for a change in the method of instruction?