MILAN KUBIATKO and KATERINA VLCKOVA

THE RELATIONSHIP BETWEEN ICT USE AND SCIENCE KNOWLEDGE FOR CZECH STUDENTS: A SECONDARY ANALYSIS OF PISA 2006

Received: 29 August 2009; Accepted: 22 January 2010

ABSTRACT. The 2006 Programme for International Student Assessment focussed on students' scientific competencies, measured their knowledge and provided questionnaires focussed on different aspects of life. One aspect was students' experience with information and communication technology (ICT). A secondary analysis of variance of the Czech Republic data (N=5,932 students) was conducted using the science knowledge test score and ICT familiarity items. The science knowledge items explored different thematic areas, such as evolution, mousepox, genetics and acid rain. The main result was that students who were connected in some way with ICT achieved better scores on the science knowledge test in comparison with students who were not. Furthermore, students whose ICT activity was connected with the educational process achieved a higher score in comparison with students whose ICT activity was not connected with the educational process.

KEY WORDS: Czech Republic, ICT, information and communication technology, large-scale data, PISA, science knowledge, students

INTRODUCTION

Information and communication technologies (ICT) can be considered a key component of modern societies and lives. Nevertheless, the public and academic discussion regarding new ICT and their influence on the educational process and results is continuing. The question is often put whether ICT can really support and improve learning and the quality of instruction and, additionally, in which way, under which conditions and for what it can be useful. The current research focusses on more specialised questions regarding different aspects and conditions of using ICT and educational results.

This study addresses these questions by analysing high-quality data drawn from the Programme for International Student Assessment (PISA), which in 2006 included an ICT familiarity questionnaire. We were particularly focussed on finding differences in students' scientific literacy and the use of computers outlined in previous studies (Anderson, Lin, Treagust, Ross & Yore, 2007; Yore, Pimm & Tuan, 2007).

International Journal of Science and Mathematics Education (2010) 8: 523–543

The OECD Programme for International Student Assessment

PISA is an internationally standardised triennial survey of the knowledge and skills of 15-year-olds. It is the product of collaboration between participating countries and economies through the Organisation for Economic Co-operation and Development (OECD); it draws on leading international expertise to develop valid comparisons across countries and cultures. The Czech Republic has participated in PISA since its introduction in 2000. PISA 2006 was focussed on students' scientific competencies—not merely on whether students can reproduce what they have learned in science but also on how well they can extrapolate from what they have learned and apply their knowledge in new situations. PISA 2006 defines science competency as the extent to which a student (a) possesses scientific knowledge and uses that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; (b) understands the characteristic features of science as a form of human knowledge and enquiry; (c) shows awareness of how science and technology shape our material, intellectual and cultural environments and (d) engages in science-related issues and with the ideas of science, as a reflective citizen (OECD, 2007).

The science items assessed students' ability to perform scientific tasks in a variety of situations, ranging from those that affect their personal lives to wider issues for the community or the world. These tasks measured students' performance in relation both to their science competencies and to their scientific knowledge. The main aim is to measure how well students are prepared to meet the challenges of today's knowledge societies. PISA 2006 introduced an ICT questionnaire to document use and activities. ICT was considered as one of a vast number of variables influencing a student's performance.

ICT Opportunities, Learning and Instruction

Recently, ICT has rapidly acquired an important place in society (Wang, 2008) and is used increasingly as a learning tool in all forms and at all levels of education (Demiraslan & Usluel, 2008). Students differ in their experiences with and attitudes toward ICT. At home, not all children have the same access to ICT, and they may use ICT resources available at home differently than at school. Therefore, differences in ICT knowledge and skills develop amongst students. Because of these differences, the increasing role of ICT as a learning tool can cause problems for students with less experience with technology or less affinity for ICT (Volman, Van Eck, Heemsker & Kuiper, 2004).

ICT can enhance knowledge sharing by lowering temporal and spatial barriers between knowledge workers and improving access to information about knowledge (Sohail & Daud, 2009). The introduction of ICT in compulsory schooling and related changes in the curriculum include a greater focus on student activity and responsibility. At the same time, the role of the teacher is expected to change (Jedeskog & Nissen, 2004). Computers may be located in a computer laboratory, distributed throughout the school, or students may use their own laptop computers. ICT may be a subject in its own right or may be used across all areas of the curriculum. How ICT is used in the school setting is important in providing students with the skills to participate in a knowledge society (Ainley, Banks & Fleming, 2002).

Contemporary settings are now favouring curricula that promote competency and performance. Curricula are starting to emphasise capabilities and to be concerned more with *how* the information is used than *what* the information is about. The moves to competency-based and performance-based curricula are well supported and encouraged by emerging instructional technologies, which tend to require:

- Access to a variety of information sources
- Access to a variety of information forms and types
- Student-centred learning settings based on information access and inquiry
- Learning environments focussed on problem-centred and inquiry-based activities
- Authentic settings and examples
- Teachers as coaches and mentors rather than content experts (Stephenson, 2001).

The growing use of ICT as an instructional medium is changing and will likely continue to change many of the strategies employed by both teachers and students in the learning process. Technology has the capacity to promote and encourage the transformation of education from a teacher-directed enterprise into one that supports more student-centred models (Robertson, 2005). Evidence of this today is manifested in the proliferation of capability-, competency- and outcomes-focussed curricula; moves towards problem-based learning; increased use of the Web as an information source and Internet users being able to choose the experts from whom they will learn. The use of ICT in educational settings acts in itself as a catalyst for change in this domain. ICT by its very nature comprises tools that encourage and support independent learning and knowledge construction. Students using ICT become immersed in the process of learning; and as more and more students use computers as information sources and cognitive tools (Smeets, 2005), the influence of the technology on how they learn will continue to increase.

When ICT was used in the curriculum, including in science, a majority of students took greater responsibility for their own learning as a result (Beauchamp & Parkinson, 2005). Reynolds, Treharne & Tripp (2003) investigated the impact of ICT on students' achievements in science (amongst other subjects) and provided evidence that they spent longer time on learning tasks.

The successful use of ICT can stimulate change in pedagogical practice—although the question of whether this enhances student learning requires further investigation. The pedagogical approach adopted in traditional classes has been shown to have a major influence on students' cognitive achievements. The teacher's competence and confidence in using ICT is an important factor in the success of student learning, but it is not enough on its own. An understanding of how ICT supports and enhances the learning task may be even more vital. Early evidence suggested, for example, that students struggled to make sense of their learning tasks when given insufficient information and guidance from the teacher (Baggott la Velle, McFarlane & Brawn, 2003).

When using ICT in science, students developed novel strategies for problem solving by building models and creating new rules (Dede & Palombo, 2004). The scaffolding effect built into the software has been related to students' ability to complete tasks of greater cognitive complexity (Speier, Vessey & Valacich, 2003). Several studies suggest that using ICT fosters in students the ability to develop higher order thinking skills (Kennewell & Morgan, 2006; Lim & Tay, 2003; Reece, 2005) and to engage in complex, causal reasoning (Dondlinger, 2007). Students have also been shown to use more exploratory language to arrive at choices through discussion (Shachaf, 2008).

Learners commonly experience difficulty in applying the appropriate knowledge for solving a novel problem; therefore, a transformation strategy is needed to supplement and/or transform their existing knowledge base (Baggott la Velle et al., 2003). There are indications that the dynamic representation of systems—and the ability to interact with these representations, which ICT enables—can assist children in developing an understanding that allows them to recognise the relevance of that experience in novel situations (Lin, Lee & Chen, 2004; Wood, 2009). The cognitive tools embedded in ICT and the pedagogical content knowledge involved provides a powerful driver for the knowledge transformation that enables students to understand a new problem (Baggott la Velle, Watson & Nichol, 2001).

ICT resources for education are part of that learning environment, and their effects are expressed in a social context with a rich, multimedia and multimodal learning environment (Preston, 2008). Teaching with these ICT is said to offer more time for teacher intervention with all students and interactions with students, greater sharing of class results and more time for students to observe, think and analyse rather than be preoccupied with gathering and processing data (Finlayson & Rogers, 2003). Research has also identified the important influence of the teacher who decides how the ICT resources are chosen (Castillo, 2006), how they are used in schools and classrooms and how students interact with the materials (Hennessy, Ruthven & Brindley, 2005). Therefore, the teacher's input crucially affects the impact of ICT use on student learning (Cox & Marshall, 2007).

Various government surveys have shown that teachers' ICT use is usually confined to very few types (e.g. using an interactive whiteboard for whole-class demonstrations or using word-processing for creative writing). Furthermore, regular uses reported by teachers may mean only a few minutes of use by individual students or extensive use by some and much less by others. This variation in use will clearly affect any impact that an ICT resource may have on student learning (Cox & Abbott, 2004; Munro, 2002; Wentling, Park & Peiper, 2006).

Previous research has also shown that different types of ICT resources have different effects on learning, for example, the use of science simulations to correct students' misconceptions and alternative frameworks (Cox, 2000), the use of data-handling software to improve students' abilities to apply binary logic (Cox & Marshall, 2007) and the use of word processing in English to reduce mistakes in punctuation and grammar (Charness, Kelley, Bosman & Mottram, 2001).

It is clear from these and numerous other examples that ICT's contributions to student learning is highly dependent upon the type of ICT resource and the subject in which it is being used. Any impact on learning can be assessed by investigating the specific nature of the ICT-based tasks and the types of concepts, skills and processes that it might affect. There is, therefore, a dilemma for researchers between the need to investigate very selected uses of ICT through an in-depth case-study approach or to conduct a large-scale study that may produce results that are more generalisable but will be limited because it does not have data in sufficient detail on the specific uses made by each learner (Cox & Marshall, 2007).

Positive influence of ICT on the teaching of science in the school as well as on consequent science literacy could be achieved by means of a wide variety of opportunities. Students should have access to wide bodies of data, such as real-time air pollution measurements and epidemiological statistics or direct links to high-quality astronomical telescopes, and to a wealth of information about science in the making. Access to secondary resources and data, however, places greater emphasis on the need to provide a science education that seeks proficiency as its ultimate goal and to develop higher-order cognitive skills of evaluation and interpretation of evidence, which requires critical assessment of the validity of theories and explanations. Such an education would seek to support and develop students' scientific reasoning, critical reflections and analytical skills. The established model of using ICT to support school science subjects assumes an iterative, investigative approach as embedded in national curricula as it incorporates simultaneous learning about scientific theory and process (Osborne & Hennessy, 2003).

The use of ICT, particularly the tools for data handling and graphing, can speed up and effect working processes, notably the more arduous and routine components. This frees students from setting up experiments, taking complex measurements, tabulating data, drawing graphs by hand and executing multiple or difficult calculations. It enables rapid plotting of diverse variables within a short period of time or collection and comparison of large numbers of results (Ruthven, Hennessy & Brindley, 2004). An interactive computer simulation can help students avoid getting bogged down with the mechanics of simply setting up equipment. For example, constructing and testing a circuit where the proliferation of wires involved can make it difficult to see what is actually happening, and minor faults in physical connections can pose a complete impediment (Hitch, 2000).

Using ICT also allows teachers and students to observe or interact with simulations, animations or phenomena in novel ways that may be too dangerous, complex or expensive for the school laboratory. The use of a data logger can facilitate otherwise impossible demonstrations, such as measuring energy transfer as a hot liquid cools. Digital video capture offers an alternative to data logging; repeated and slow-motion playback allows phenomena that are difficult for a whole class to view or events otherwise too slow (e.g. growth of a plant) or fast (e.g. sound waves or the behaviour of two different masses dropped from the same height) to be captured. The Internet also offers some unique opportunities to experience phenomena, such as a view of the Earth from a moving satellite (Finlayson & Rogers, 2003; Osborne & Hennessy, 2003).

The Czech Republic was integrated into the "Benchmarking Access and Use of ICT in European Schools" research programme in 2006, in which data were obtained from head teachers and classroom teachers in 27 countries (Korte & Hüsing, 2007). The surveys sought information on ICT equipment and the Internet in schools, their use in classrooms, teachers' attitudes to ICT use, results on access, competence and motivation for using ICT in schools and ICT readiness of teachers. The Czech Republic results give the number of computers per 100 pupils as 9.3 and the number of computers connected to the Internet per 100 pupils as 8.2. In the Czech Republic, 63% of schools have broadband Internet access and 48% provide computers in classrooms (Korte & Hüsing, 2007). By this time, these percentages might be higher as the numbers of people connected to the Internet and of computers in schools increase every year.

Methodology

The aim of this study was to explore the relationships amongst students' science achievement and their self-reported ICT access and engagement in schools, homes and other settings. The secondary analysis was designed to use data from the PISA 2006 Czech Republic knowledge test and ICT questionnaire. Research questions were established in relation to the aim of the study:

1. Are there any differences in knowledge scores between students who used computers and those who did not?
2. Are there any differences in knowledge scores between students who have been using a computer for a long time and those who did not?
3. Are there any differences in knowledge scores between students regarding the time spent using the computer at different places?
4. Are there any differences in knowledge scores between students regarding frequency and type of computer use?
5. Are there any differences in knowledge scores between students who were good at the activities related to ICT and those who were not?

ICT Science Knowledge Test and Questionnaire

The items on the science knowledge test focussed on animate and inanimate nature and concerned different thematic areas, such as evolution, mousepox, genetic and acid rain. The test items and student responses were in written and graphic form. Individual items were weighted differently in the final score; for each question, students obtained 0 points minimum and 3 points maximum. The knowledge test was standardised at the national and international levels, and it showed adequately high reliability. There were subquestions in each question. We used an overall average score for each student in the study. The value of every question varied between 0 and 3 points. The score from the knowledge test, the dependent variable, was used in the statistical evaluation and used to calculate descriptive statistics: means and standard deviations. The sample size of students from the Czech Republic was 5,932, with 2,786 girls and 3,146 boys. The students were 15 years old and attending the ninth year of elementary school (i.e. lower secondary level, at the end of compulsory education) or the first year of upper secondary vocational school or grammar school.

The ICT questionnaire was part of the student survey and was divided into five areas with one question for each area, as follows:

1. *Have you ever used a computer?* This question was dichotomous (yes–no).
2. *How long have you been using computers?* This question contains a four-point frequency scale (less than 1 year–1 year or more–3 years or more–5 years or more).
3. *How often do you use a computer at the following places?* This question was related to the amount of time the computer was used at home, at school or elsewhere and was measured on a five-point frequency scale (almost every day–once or twice a week–a few times a month–once a month or less–never).
4. *How often do you use computers for the following reasons?* This question rated the frequency of computer use for 11 activities on a five-point scale (almost every day–a few times each week–between once a week and once a month–less than once a month–never).
5. *How well can you do each of these tasks on a computer?* The last question asked students to rate their ability on a four-point scale (I can do this very well by myself–I can do this with help from someone–I know what this means but I cannot do it–I do not know what this means).

Statistical Procedure

The score in the science knowledge test was defined as the dependent variable. The responses on the ICT questionnaire were used as the independent variable. The first two analyses did not address any subquestions; therefore, responses to each question served as an independent variable. The other analyses included subquestions; therefore, the responses to each subquestion served as an independent variable. It means that every subquestion was presented as individual. For example, question 3 was “Are there any differences in knowledge scores between students regarding the time spent using the computer at different places?" with three subquestions of at home, at school and at other places. Each subquestion was evaluated independently. The situation in questions 4 and 5 was similar. We analysed the influence of independent variables on the knowledge scores. One-way analyses of variance (ANOVAs; *Statistica 8*) were used to test differences in science achievement for significance for specific item responses on the ICT questionnaire. Because every question except question 1 contained more than two options, it was necessary to use a post hoc pair-wise comparison to obtain better and more detailed explanation of the results. The nonresponse rate varied between 0.1% and 3% for each ICT item; therefore, we decided to exclude data sets containing items without responses to avoid potential bias.

Results

The results are structured in five areas and correspond to the items of the ICT questionnaire. Discussion and conclusions follow.

Question 1: Are there any differences in knowledge scores between students who used computers and those who did not?

Student responses regarding computer usage indicated almost all (96.83%) had used computers. These students scored significantly higher on the mean achievement score than students who had not used computers ($F(2, 5{,}928)=14.93$; $p=0.001$; $\eta^2=0.07$). The mean achievement score for computer users was 1.12 with a standard deviation of 0.01; for nonusers, it was 0.89 with a standard deviation of 0.05.

Question 2: Are there any differences in knowledge scores between students who have been using a computer for a long time and those who did not?

Student responses regarding length of time of computer usage were recorded on a four-point ordered frequency scale. The responses to the question showed a relationship between science achievement and length of computer use (Figure 1). Students who had used computers the longest achieved the highest mean scores on the knowledge test whereas students who had used computers for the shortest time achieved the lowest scores ($F(4, 5{,}926)=25.14$; $p<0.001$; $\eta^2=0.13$). The possibility of less than 1 year was selected by 3.76% of the respondents (includes nonusers from question 1), 1 year or more by 12.26%, 3 years or more by 26.97% and 5 years or more by 53.62%. Post hoc Tukey's honestly significant

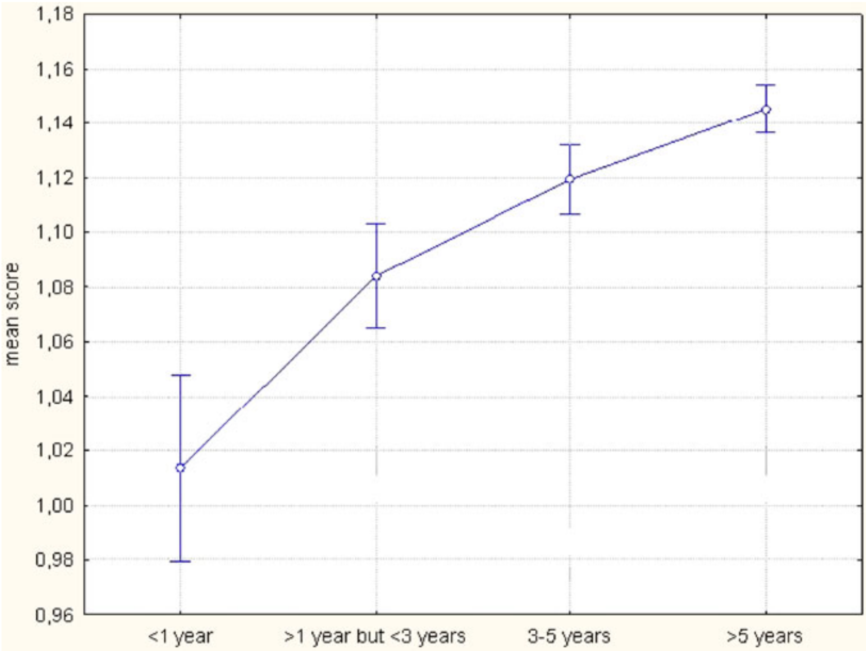

Figure 1. Relation between mean knowledge test score and length of computer use

difference test revealed statistically significant (p<0.05) differences between the response groups.

Question 3: Are there any differences in knowledge scores between students regarding the time spent using the computer at different places?

Student responses regarding length of time of computer usage were recorded on a five-point frequency scale. Table 1 provides F value, effect size, mean score and percentage of respondents for each possible answer. A statistically significant difference in knowledge score was found in using a computer at home (F(5, 5,925)=23.05; p<0.001; η^2=0.14); students who used a computer at home once or twice a week achieved the highest mean score on the knowledge test whereas students who never used a computer at home achieved the lowest mean score. A statistically significant difference in knowledge score was also found in using a computer at school (F(5, 5,925)=22.60; p<0.001; η^2=0.14); students who used a computer almost every day achieved the highest mean score whereas students who never used a computer achieved the lowest mean score on the knowledge test. Students also differed in the knowledge score for computer use at other places (F(5, 5,925)=14.38; p<0.001; η^2=0.11); most successful were students who used a computer once a month or less

TABLE 1

ANOVA values for each reason, effect size, mean score of answer possibilities and percentage score of each possibility

Places for using a computer	F^{a}	η_2	*a*	%	*b*	%	*c*	%	*d*	%	*e*	%
School	23.05	0.14	1.13	70.43	1.16	11.61	1.11	4.35	1.07	1.90	1.02	6.30
Home	22.60	0.14	1.15	8.33	1.14	58.38	1.10	16.01	1.09	6.91	1.04	4.86
Other places	14.38	0.11	1.09	5.65	1.12	13.10	1.14	20.55	1.14	25.05	1.12	29.16

a almost every day, *b* once or twice a week, *c* a few times a month, *d* once a month or less, *e* never
[a]The statistically significant difference of each *F* value is $p<0.001$

whereas the lowest mean score was recorded by students who used a computer almost every day.

Question 4: Are there any differences in knowledge scores between students regarding frequency and type of computer use?

Student responses regarding frequency and reasons for computer usage were recorded on a five-point frequency. Table 2 lists 11 reasons for computer use, with the *F* value, effect size, mean score and percentage of respondents for each possible answer. The majority of responses were as anticipated. Students who used ICT more often achieved better knowledge scores. Only three cases (i.e. playing games, educational software, creating programmes) achieved lower knowledge scores.

Question 5: Are there any differences in knowledge scores between students who were good at the activities related to ICT and those who were not?

Student responses regarding proficiency on specific computer tasks were recorded on a four-point competency scale for 16 tasks. Table 3 provides *F* value, effect size, mean score and percentage of respondents for each possible answer. The *F* values are significant at $p<0.001$ for proficiency on all reported tasks. Students who responded *I can do this very well by myself* achieved the highest mean score on the knowledge test in every task except the last one, where the most successful students responded *I know what this means, but I cannot do it*. The lowest knowledge score was recorded by students who responded in all tasks *I do not know what this means*, except for the *create database* task, where the lowest knowledge score was recorded by students who responded *I know what this means, but I cannot do it*.

TABLE 2

ANOVA values for each reason, science knowledge, mean score of answer possibilities and percentage score of each possibility

Reasons for using a computer	F^{a}	η^2	*a*	%	*b*	%	*c*	%	*d*	%	*e*	%
Browse the Internet for information	32.78	0.16	1.15	35.17	1.14	33.13	1.12	17.30	1.06	6.25	1.00	4.30
Play games	16.63	0.12	1.10	29.86	1.13	21.46	1.16	17.03	1.16	14.48	1.09	13.13
Write documents	41.13	0.18	1.13	13.12	1.16	31.36	1.14	32.10	1.07	12.58	1.01	7.03
Collaborate with a group or team	9.95	0.09	1.13	32.16	1.13	21.11	1.13	16.15	1.13	11.97	1.08	14.36
Use spreadsheets	27.98	0.15	1.11	6.57	1.15	16.55	1.15	28.94	1.14	23.95	1.05	19.76
Download software	10.51	0.09	1.12	24.17	1.14	18.09	1.14	16.67	1.14	13.10	1.09	23.36
Draw, paint or use graphics programmes	27.58	0.15	1.12	10.45	1.15	17.45	1.15	25.29	1.13	24.83	1.05	17.77
Use educational software	17.32	0.12	1.10	5.14	1.13	12.14	1.15	22.30	1.15	26.06	1.09	30.02
Download music	9.90	0.09	1.11	34.66	1.13	21.11	1.15	14.95	1.15	9.07	1.11	16.20
Write computer programmes	11.53	0.10	1.09	7.55	1.12	12.22	1.11	16.74	1.12	18.34	1.14	40.86
Communication (e-mail, chat)	15.61	0.11	1.13	48.72	1.14	21.07	1.13	11.60	1.12	6.19	1.05	8.43

a almost every day, *b* a few times each week, *c* between once a week and once a month, *d* less than once a month, *e* never

[a]The statistically significant difference of each F value is $p<0.001$

TABLE 3

ANOVA values for each task and the mean score of answer possibilities and the percentage score of each possibility

Tasks on a computer	F^a	η^2	*a*	%	*b*	%	*c*	%	*d*	%
Chat online	14.68	0.10	1.13	87,96	1.07	4.40	1.12	2.92	0.94	0.81
Use software to find and get rid of computer viruses	18.25	0.11	1.14	53.22	1.11	24.73	1.11	15.63	1.01	2.36
Edit digital photographs or other graphic images	25.17	0.13	1.14	64.51	1.10	19.84	1.08	9.91	0.98	1.47
Create a database	9.32	0.08	1.14	25.51	1.13	34.20	1.11	20.94	1.12	15.16
Copy data to a CD	24.29	0.13	1.14	78.02	1.10	11.09	1.07	5.56	0.96	1.47
Move files from one place to another on a computer	39.51	0.16	1.14	85.38	1.06	6.51	0.99	2.87	0.93	1.26
Search the Internet for information	30.24	0.14	1.13	91.35	1.01	2.88	0.99	1.06	0.88	0.59
Download files or programmes from the Internet	24.98	0.13	1.13	80.82	1.10	10.76	1.05	3.34	0.91	1.05
Attach a file to an e-mail message	29.54	0.14	1.14	77.38	1.08	11.82	1.07	4.96	0.97	1.70
Use a word processor	34.43	0.15	1.14	82.10	1.06	8.65	1.01	3.12	1.01	2.02
Use a spreadsheet to plot a graph	43.05	0.17	1.15	63.82	1.10	21.81	1.05	7.25	0.98	2.80
Create a presentation	32.44	0.15	1.15	61.88	1.10	19.99	1.07	9.31	1.03	4.62
Download music from the Internet	18.91	0.11	1.13	76.96	1.11	12.10	1.10	5.50	0.96	1.47
Create a multimedia presentation	14.28	0.10	1.13	46.61	1.12	32.45	1.12	14.19	1.03	2.51
Write and send e-mails	27.75	0.14	1.13	87.96	1.06	4.87	1.03	2.21	0.89	0.72
Construct a web page	15.30	0.10	1.13	29.97	1.12	36.51	1.13	27.11	1.00	2.04

a I can do this very well by myself, *b* I can do this with help from someone, *c* I know what this means but I cannot do it, *d* I do not know what this means

[a]The statistically significant difference of each F value is $p<0.001$

Discussion

This research investigated the relation between science knowledge and ICT activities, experience, proficiency and type and place of use. The first area focussed on respondents' experience with computers. Students who had used computers achieved a higher mean score on the knowledge test in comparison with those who had not. This result is in keeping with Barak (2007) and O'Neil, Wainess & Baker (2005) who found that ICT has a positive effect on learning outcome. The positive relation between using ICT and higher science-knowledge scores suggests that students using ICT have access to more information from a variety of sources related to science and human activity. Whilst textbooks might not be as attractive to different groups of students for various reasons, the interactive nature of the Internet holds their attention so that the content is better absorbed. It must be noted that the very small group of nonusers may include students with very low socioeconomic resources and less than desirable school opportunities thereby biasing the results.

In the second question, students were asked how long they had used computers. The highest scores on the knowledge test were recorded by students who had used a computer for the longest time. This again assumes that students found information with the assistance of ICT. The Internet offers a relatively unlimited amount of information, which may make it more acceptable to students than information in textbooks. Educational software, too, seems to be of greater interest to students as they can try out different illustrations, animations, experiments etc. Volman & van Eck (2001) produced a similar finding in their study. It is likely that length of use and proficiency are related; therefore, these results may contain a critical proficiency effect that may explain the nonlinear nature of the graphic display of achievement and length of use.

The third question was focussed on how often students use computers at different places (home, school or other places). Students who used the computer more frequently at home or school but not other places were the most successful in the knowledge test. It can be assumed that at school students use computers in relation to the educational process because schools allow access only to those web pages connected with educational goals, which may not be the case in other places and in some homes. Because of these controls, students are not expected to be engaged in activities that are not connected with the educational process, such as downloading movies or music or playing online games. In our findings, it was revealed that educational software and ICT applications have been integrated into the science subjects and almost every school subject. This is a change from some years ago when ICT was connected only with the subject of informatics. Currently, a variety of educational CDs in students' native language and English are available. Chambers & Davies (2001) showed that information written in a language other than the native language reduces work with ICT even though it helps the user to learn the foreign language.

Educational ICT applications have a great impact on the learning process through the combination of images, sounds, video and text. Using ICT applications usually changes the teacher's role in the learning environment. ICT tools are often used as a means for students' independent work, which gives the teacher fewer opportunities to make supplementary remarks and to stimulate reflection. In a face-to-face learning situation, teachers have more opportunity to use material in a flexible manner, to add or skip parts or to discuss information that is one-sided or biased. Vogel & Klassen (2001) found that students are more quickly prepared in lessons in which they use ICT. Encouraging students to take a more active part in the learning process is one advantage of ICT. Furthermore, as Brewer (2003) showed, using ICT in the learning process helps eliminate misconceptions.

The fourth question in the analysis focussed on how often students use ICT for some activities. Some activities were connected with school, and some were out-of-school activities. Students who used computers more frequently for educational activities (e.g. spreadsheets, writing documents etc.) achieved a higher knowledge score. One surprising result was that students who wrote computer programmes almost every day achieved the lowest mean science knowledge score. This activity was understood as being connected with the educational process but, in this case, it might be connected only with informatics. Therefore, these students may have less interest in science subjects and the consequence might be their relatively low score in the science-knowledge test. The worst score was recorded by students who most frequently performed out-of-school-type activities (e.g. playing games) that probably take up a considerable amount of time, which could be used for the learning process. Therefore, we can agree with Feinsinger (2001) that computer-based technologies can be powerful pedagogical tools and can turn the passive recipient of information into an active participant in the learning. However, we have to know how ICT should be used because it is of little instructional value if we have not clarified the goals for students' learning before bringing them into classroom.

In the final question, students indicated how well they could perform certain activities connected with ICT, such as online chat and copying data to a CD. In all activities, the most successful students were those who thought that they could do these activities well. With one exception, students who were good at constructing a web page achieved a worse score. Our interpretation of this might be similar to that of the previous case. Students interested in this activity may have less positive attitudes toward science subjects, and the consequence of this might be their low score in the science-knowledge test.

Conclusion

This secondary analysis of PISA 2006 data found a positive relationship between the use of ICT and the science knowledge of 15-year-old students in the Czech Republic—but this holds only when the use of ICT is connected with the educational process independent of the place where the ICT is used (i.e. whether at home, school or other places). Very interesting positive relations were found regarding the amount of time spent using a computer and science knowledge and regarding the decreasing variance in the knowledge scores achieved by students, which suggests the interpretation that ICT might have a supporting role in diminishing differences in achievement amongst students.

These results support the application of ICT in lower secondary and primary schools in the Czech Republic because of the strong and positive relation between the amounts of time spent using a computer and the development of a knowledge of science. The results support empirically not only the use of computers at school but also the educational effectiveness of their use at home when used for educational purposes. We are in agreement with Hand, Prain & Yore (2001), who asserted that increased use of computers focussed on specific educational reasons and knowledge-building activities (whether at school, home or elsewhere) could reduce the digital divide or gap. The results appear to provide specific guidance as to which activities are promising and which are not. The results also indicate the need for explicit instruction in the use of some activities to improve science literacy, such as the need for critical stance and critical thinking, databases, multiple representations and the transformation between representations.

Suggestions for further research might include an analysis of the relationship between the use of ICT and competencies in science, attitudes to science and mathematical and reading competencies; this could help further establish the perceived importance of ICT in education. The relationship between science knowledge and ICT should focus in further studies on different areas of scientific competency (e.g. reasoning, analysing, application) and ICT. In addition, analysis in other countries focussing on the relationship between ICT use and science knowledge can be strongly recommended to support the generalisation of this relationship across different educational and socioeconomic systems.

It appears that ICT has given us a powerful tool for the learning of science subjects. Nevertheless, the results should be interpreted with caution and a background explanation mediated through socioeconomic capital and personal characteristics (e.g. motivation, aspiration level and intelligence) taken into account. These aspects can be expected to play the role of latent variables in the connection of ICT and science knowledge. The relation between ICT use and socioeconomic status and the capital of the family can be anticipated. In addition, PISA found differences amongst schools in the Czech Republic in results in science, reading and mathematics competency. Schools might differ in the access they give students to ICT and in the amount and forms of ICT use in the instructional process or outside the classroom related to other educational activities. Nevertheless, the anticipated indirect role of all these variables in the positive relation of ICT and science knowledge does not change the importance of the main finding; that is, the use of ICT in the education process is reasonable and meaningful, not least because it fosters the acquisition of a knowledge of science.

John (2005) showed that, whilst ICT use influences the classroom culture, the classroom culture also influences ICT use. Therefore, it is very important to look at ICT applications not only from a static point of view but also whilst it is in actual use. The learning environment as students experience it comprises the ICT tool, the teacher and his or her teaching and the interactions in the class. It is the teacher's task to challenge the students and to motivate and support them in the learning process and knowledge construction. Baylor & Ritchie (2002) argued that the effective use of computers in the classroom requires the teacher to use computer management and instructional strategies that include supporting cultural and individual learning preferences, flexibility in classroom seating, the mobility and grouping of students and giving students options and autonomy.

The successful use of ICT in the teaching process is not an obvious process. Teachers and students have to gain the confidence to use ICT and to learn with its assistance. Results show that ICT has a positive potential for science knowledge; therefore, it is important to continue to implement ICT in the teaching process. Teachers should learn both how to use ICT and how to teach effectively with ICT. This is not only a task for faculties and schools that train teachers; the managements of schools are being challenged to offer teachers different courses and better access to the Internet, where teachers can share information relevant to education. Second, it is important to understand that the incorporation of ICT in the teaching process needs time. Exploring new technologies and how to use them effectively takes more time than making minor adjustments to old lessons from year to year. Bringing ICT to the classroom is a continuing investment. Third, the use of ICT is generally helpful for making changes in classroom organisation and teaching methods to retain students' attention. Most students prefer a mixed-mode learning environment, that is, a combination of face-to-face interaction and online activities. Teachers and students can build an effective co-learning partnership where they develop their ICT knowledge and teaching expertise together.

Acknowledgements

This paper was supported by the Ministry of Education, Youth, and Sport of the Czech Republic as part of the Centre for Basic Research on Schooling project (LC06046) and KEGA 3/6235/08. The authors would like to thank OECD and PISA for the freely available data used in this analysis. We would like to thank Andrew Oakland and Sharyl Yore, who kindly improved the English of the paper.

References

Ainley, J., Banks, D., & Fleming, M. (2002). The influence of IT: Perspectives from five Australian schools. *Journal of Computer Assisted Learning, 18*(4), 395–404.

Anderson, J. O., Lin, H.-S., Treagust, D. F., Ross, S. P., & Yore, L. D. (2007). Using large-scale assessment datasets for research in science and mathematics education: Programme for International Student Assessment (PISA). *International Journal of Science and Mathematics Education, 5*(4), 591–614.

Baggott la Velle, L. M., Watson, K. E., & Nichol, J. D. (2001). OtherScope—the virtual microscope—can the real learning experiences in practical science be simulated? *International Journal of Healthcare Technology and Management, 2*(5/6), 539–556.

Baggott la Velle, L. M., McFarlane, A., & Brawn, R. (2003). Knowledge transformation through ICT in science education: A case study in teacher-driven curriculum development. Case study 1. *British Journal of Educational Technology, 34*(2), 183–199.

Barak, M. (2007). Transition from traditional to ICT-enhanced learning environments in undergraduate chemistry courses. *Computers & Education, 48*(1), 30–43.

Baylor, A. L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers & Education*, *39*(4), 395–414.

Beauchamp, G., & Parkinson, J. (2005). Beyond the 'wow' factor: Developing interactivity with the interactive whiteboard. *School Science Review, 86*(316), 97–103.

Brewer, C. (2003). Computer in the classroom: How information technology can improve conservation education. *Conservation Biology, 17*(3), 657–660.

Castillo, N. (2006). *The implementation of information and communication technology (ICT): An investigation into the level of use and integration of ICT by secondary school teachers in Chile*. Unpublished doctoral dissertation, King's College London, University of London, England.

Chambers, A., & Davies, G. (2001). *ICT and language learning. A European perspective*. Lisse, The Netherlands: Swets & Zeitlinger.

Charness, N., Kelley, C. L., Bosman, E. A., & Mottram, M. (2001). Word processing training and retraining: Effects of adult age, experience, and interface. *Psychology and Aging, 16*(1), 110–127.

Cox, M. J. (2000). Information and communication technologies: Their role and value for science education. In M. Monk & J. Osborne (Eds.), *Good practice in science teaching—what research has to say* (pp. 142–158). Buckingham, England: Open University Press.

Cox, M. J., & Abbott, C. (2004). *ICT and attainment: A review of the research literature*. London: British Educational Communications & Technology Agency, Department for Education & Skills.

Cox, M. J., & Marshall, G. (2007). Effects of ICT: Do we know what we should know? *Education and Information Technologies Journal, 12*(1), 59–70.

Dede, C., & Palombo, M. (2004). Virtual worlds for learning. *Threshold* (Summer), 16–20.

Demiraslan, Y., & Usluel, Y. K. (2008). ICT integration processes in Turkish schools: Using activity theory to study issues and contradictions. *Australasian Journal of Educational Technology, 24*(4), 458–474.

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology, 4*(1), 21–31.

Feinsinger, P. (2001). *Designing field studies for biodiversity conservation*. Washington, DC: Island Press.

Finlayson, H., & Rogers, L. (2003). Does ICT in science really work in the classroom? Part 1: The individual teacher experience. *School Science Review, 84*(309), 105–111.

Hand, B., Prain, V., & Yore, L. D. (2001). Sequential writing tasks' influence on science learning. In P. Tynjälä, L. Mason, & K. Lonka (Eds.), *Writing as a learning tool: Integrating theory and practice* (pp. 105–129). Dordrecht, The Netherlands: Kluwer.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: Commitment, constraints, caution and change. *Journal of Curriculum Studies, 37*(2), 155–192.

Hitch, M. (2000). Another dimension: Introducing ICT into science lessons is easy, time-saving and enjoyable. *Times Educational Supplement Curriculum Special*, Spring, pp.18–19.

Jedeskog, G., & Nissen, J. (2004). ICT in the classroom: Is doing more important than knowing? *Education and Information Technologies, 9*(1), 37–45.

John, P. (2005). The sacred and the profane: Subject sub-culture, pedagogical practice and teachers' perceptions of the classroom uses of ICT. *Educational Review, 57*(4), 471–490.

Kennewell, S., & Morgan, A. (2006). Factors influencing learning through play in ICT settings. *Computers & Education, 46*(3), 265–279.

Korte, W. B., & Hüsing, T. (2007). Benchmarking access and use of ICT in European schools 2006: Results from head teacher and a classroom teacher surveys in 27 European countries. *eLearning Papers, 2*(1). Available from http://www.elearningeuropa.info/files/media/media11563.pdf.

Lim, P. C., & Tay, L. Z. (2003). Information and communication technologies (ICT) in an elementary school: Students' engagement in higher order thinking. *Journal of Educational Multimedia and Hypermedia, 12*(4), 425–451.

Lin, J. M. C., Lee, G. C., & Chen, H. Y. (2004). Exploring potential uses of ICT in Chinese language arts instruction: Eight teachers' perspectives. *Computers & Education, 42*(2), 133–148.

Munro, R. (2002). Curriculum focused ICT—the critical resource. In D. M. Watson & J. Andersen (Eds.), *Networking the learner. Computers in education* (pp. 179–188). Boston: Kluwer.

O'Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. *The Curriculum Journal*, *16*(5), 455–474.

Organisation for Economic Co-operation and Development (2007). *PISA 2006 science competencies for tomorrow's world* (vol. 1: Analysis). Paris: Author.

Osborne, J., & Hennessy, S. (2003). *Literature review in science education and the role of ICT: Promise, problems and future directions*. Futurelab Report No. 6. Available from http://www.futurelab.org.uk/resources/documents/lit_reviews/Secondary_Science_Review.pdf.

Preston, C. J. (2008). Braided learning: An emerging process observed in e-communities of practice. *International Journal of Web Based Communities, 4*(2), 220–243.

Reece, G. J. (2005). Critical thinking and cognitive transfer: Implications for the development of online information literacy tutorials. *Research Strategies, 20*(4), 482–493.

Reynolds, D., Treharne, D., & Tripp, H. (2003). ICT—the hopes and the reality. *British Journal of Educational Technology, 34*(2), 151–167.

Robertson, S. L. (2005). Re-imagining and rescripting the future of education: Global knowledge economy discourses and the challenge to education systems. *Comparative Education*, *41*(2), 151–170.

Ruthven, K., Hennessy, S., & Brindley, S. (2004). Teacher representations of the successful use of computer-based tools and resources in teaching and learning secondary English, Mathematics and Science. *Teaching and Teacher Education, 20* (3), 259–275.

Shachaf, P. (2008). Cultural diversity and information and communication technology impacts on global virtual teams: An exploratory study. *Information & Management, 45* (2), 131–142.

Smeets, E. (2005). Does ICT contribute to powerful learning environments in primary education? *Computers & Education, 44*(3), 343–355.

Sohail, M. S., & Daud, S. (2009). Knowledge sharing in higher education institutions: Perspectives from Malaysia. *VINE, 39*(2), 125–142.

Speier, C., Vessey, I., & Valacich, J. S. (2003). The effects of interruptions, task complexity, and information presentation on computer-supported decision-making performance. *Decision Sciences, 34*(4), 771–797.

Stephenson, J. (Ed.). (2001). *Learner-managed learning—an emerging pedagogy for online learning*. *Teaching and learning online: Pedagogies for new technologies*. London: Kogan Page.

Vogel, D., & Klassen, J. (2001). Technology-supported learning: Status, issues and trends. *Journal of Computer Assisted Learning, 17*(1), 104–114.

Volman, M., & Van Eck, E. (2001). Gender equity and information technology in education: The second decade. *Review of Educational Research, 71*(4), 613–634.

Volman, M., Van Eck, E., Heemsker, I., & Kuiper, E. (2004). New technologies, new differences. Gender and ethnic differences in pupils' use of ICT in primary and secondary education. *Computers & Education, 45*(1), 35–55.

Wang, T. J. (2008). Using ICT to enhance academic learning: Pedagogy and practice. *Educational Research and Review, 3*(4), 101–106.

Wentling, T. L., Park, J., & Peiper, C. (2006). Learning gains associated with annotation and communication software designed for large undergraduate classes. *Journal of Computer Assisted Learning, 23*(1), 36–46.

Wood, D. (2009). Comments on "Learning with ICT: New perspectives on help seeking and information searching." *Computers & Education, 53*(4), 1048–1051.

Yore, L. D., Pimm, D., & Tuan, H.-L. (2007). The literacy component of mathematical and scientific literacy. *International Journal of Science and Mathematics Education, 5* (4), 559–589.

Educational Research Centre, Faculty of Education Masaryk University
Porici 31, 603 00, Brno, Czech Republic
E-mail: mkubiatko@gmail.com