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The effect of an ICT-based teacher training programme – based on a social constructivist model- on the teaching and learning activities in primary schools in the Ecuador setting

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Prefacio

La presente disertación representa el trabajo de cinco años y fue diseñada para contribuir con la investigación, desarrollo y mejoramiento de la educación primaria en Ecuador. Sin embargo, este producto no es solo un esfuerzo individual sino el de un equipo de trabajo. A continuación expreso mi gratitud a aquellos que contribuyeron en el desarrollo de este proyecto de investigación.

En primer lugar quiero darle gracias a Dios, si no fuera por Él nada sería posible. Luego a mi familia, pues este trabajo es también suyo. Esta tesis es el resultado de la perseverancia, paciencia, y amor que siempre me brindaron. Gracias a mi esposo Jaime, a mis hijos Giselle y Luis Andrés, quienes también me dieron inspiración para escribir esta disertación. A mis padres Julia y Victor, quienes me enseñaron a confiar y a poner siempre lo mejor de mí en cada tarea y a mis hermanos, Cinthia y Victor.

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Preface

The present dissertation represents the work of five years. It was designed to contribute to the research, development and enhancement of primary education in Ecuador. However, this product is not only an individual endeavour but a team-work one. I would like to express my gratitude to the people who contributed for the development of this research project.

First, I want to thank God, without Him nothing would be possible. Next to my family; this work is also theirs. This thesis is the result of the perseverance, patience, and love they always gave me. Thanks to my husband, Jaime and to my children: Giselle and Luis Andrés, who were my inspiration to write this dissertation. Thanks to my parents Julia and Victor, who taught me to trust myself, and do my best, and to my sister and brother, Cinthia and Victor.

I am particularly grateful to my promoter, Martin Valcke, who trusted in me. His guide and contribution were very important during the development of the whole research. Additionally, I would like to thank the supervisor committee of this thesis: Enrique Peláez, Ronald Soetaert and Elena Fernández.

The teachers and children from the schools of the Peninsula region deserve special recognition for allowing me to come into their classrooms to observe and for their determination and carefulness about their work during all these years. Special thanks to the Rector of ESPOL to believe in the innovation of education through technology.

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Katherine Chiluiza García
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General Introduction

The effect of an ICT-based teacher training programme –based on a social constructivist model- on the teaching and learning activities in primary schools in the Ecuador setting

The evolution and capabilities of Information and Communication Technologies (ICT) have transformed our lives; in such a way that it is said that we live in the *information society* or *knowledge society* (Kozma, 2003). Education as any other field has also been influenced by ICT. In this sense teaching and learning could be improved by the transformative "capabilities" of ICT (ETS, 2002). The benefits of using ICT in education are linked to a set of potentialities and possibilities that promotes the development of skills needed in our society e.g., team-work, critical thinking, use newly built knowledge and information, and the consecutive adoption of long-life learning skills (Burns & Ungerleider, 2003; Cox et al., 2004a; Henderson, Klemes, & Eshet, 2000; Mc Guiness, 1999; Murphy et al., 2002; Valdez et al., 2000; Waxman, Lin, & Michko, 2003). Moreover, these new technologies are seen currently as *mindtools*, because they might function as *intellectual tool kits* and as *intellectual partners* that allow the citizen of the third millennium to create new knowledge, to reflect on the process of their own learning, to engage in critical thinking about a subject, to help them in internal negotiations and meaning making, to construct personal representations of meanings, and to support mindful thinking, among others (Jonassen, 1996; Jonassen & Marra, 1994; Jonassen, Carr, & Yueh, 1998; Jonassen, Howland, Moore, & Marra, 2003; Wegerif, 2004).

Nevertheless, the positive perceptions and expectations about the impact and relevance of ICT in education have recently been questioned due to the sharp contrast between the great investments governments all over the world have put in the educational implementation of ICT and the lack of research evidence that demonstrates improvement of teaching practices and learning performance (Becker, 2001; Burns et al., 2003; Conlon & Simpson, 2003; Cuban, 2001; Reynolds, Treharne, & Tripp, 2003; Waxman, Connell, & Gray, 2002; Waxman et al., 2003; Wenglinsky, 1998). The available research presents three main problems. It is the intention of the research

presented in this PhD-thesis to take these problems into consideration when studying the general research problem as presented in the title.

The first problem is related to research about *the impact of ICT teacher training on the learning processes and performance of pupils* (Adams & Chapman, 2002; Knierzinger, Røsvick, & Schmidt, 2002; Russel & McPherson, 2001; Wood, Underwood, & Avis, 1999). Even though there is plenty of research about ICT teacher training, the link between teacher training (pre-service and/or in-service) and the impact on pupils' attainments and skills development in ICT-based environments has hardly been researched (Kynigos & Argyris, 2004; Richardson & Placier, 2001). A critical factor in this context is whether teachers actually adopt and implement the newly learned teaching strategies in their ICT based and non-ICT based teaching practices. Research indicates that the actual adoption of techniques, strategies, or knowledge learned during ICT teacher training is closely related to the following factors: (a) previous experience as a teacher-student which in turn is linked to teachers' beliefs (Murphy, Delli, & Edwards, 2004; Fang, 1996); and (b) conceptions of learning (Bolhuis & Voeten, 2004); and (c) the concrete payback on their pupils' outcomes through the innovation (Reynolds et al., 2003; Butler & Wiebe, 2003).

From the elements put forward above teachers' educational assumptions, perceptions about teaching and learning are closely related to their actual teaching behavior (Cox et al., 2004b; Kirschner & Davies, 2003; Knierzinger et al., 2002). These perspectives influence the way ICT is used in the classroom. Teachers with traditional assumptions or perceptions about learning and instruction - unidirectional instruction - prefer skills-based software; whereas teachers adopting constructivist assumptions and perceptions about teaching and learning favor skills-based as well as open-ended ICT tools (Smeets & Mooij, 2001; Becker, 2001; Riel & Becker, 2000).

These considerations stress the crucial role of both pre-service and in-service teacher training. A review of the literature about trends in teacher education and the identification of exemplary teaching practices points at two critical changes in teacher training: (a) the need of a pedagogical shift i.e., moving from the traditional, unidirectional transmission model of teaching to a constructivist teaching that incorporates ICT in a relevant way in classroom practices (Kirschner et al., 2003; Niemi, 2003; Gonzales, Picket, Hupert, & Martin, 2002; Russel et al., 2001; Yelland, 2002) and (b) the adoption of the constructivist approach in the implementation of the

actual teacher training programmes, with the inclusion of appropriate ICT-tools (Casey, Harris, & Rakes, 2004; SITE, 2004; Kozma & McGhee, 2003; Wood et al., 1999). These critical changes are key to produce the necessary epistemological changes in teachers' philosophies and the further inclusion of ICT as transformative tools in teaching and learning environments (Cox et al., 2004b; Dawes, Horan, & Hackett, 2000; Howard, McGee, Schwartz, & Purcell, 2000; Pedersen & Liu, 2003).

Next to teacher assumptions and perceptions, also the assumptions and perceptions of the pupils can be put forward as a way to explain the outcomes of ICT adoption in the classrooms. However, there is the lack of research adopting this approach (Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998; Lee & Fraser, 2001).

The second problem is related to *what to measure* when analyzing changes in pupil performance. Available meta-analyses of research report on cognitive (subject knowledge) and non-cognitive outcomes (attitudes, motivation) of pupils as related to immersion in ICT-based learning environments (Waxman et al., 2002; Waxman et al., 2003; Wenglinsky, 1998; Kulik, 2003; Valdez et al., 2000; Suomala & Alajaaski, 2002). The impact on subject knowledge outcomes is in particular related to basic skills development. Several studies have e.g., reported positive outcomes in the mathematics domain (Cox et al., 2004a; Mc Guiness, 1999; Murphy et al., 2002). Other research focused more on the influence on cognitive functioning. In this context, it is interesting to look at the studies that researched the Logo-programming language and educational Logo-based environments. The cognitive outcomes identified as a consequence of Logo-use (and a related appropriate instructional approach) are higher-levels of mathematical thinking, a more generalized and abstract view of mathematical objects, a deeper conceptualization of fundamental concepts in geometry, and the development of problem-solving skills (Clements & Nastasi, 1992; Clements & Nastasi, 1999; De Corte, 1993; Hoyles & Noss, 1990). These positive results are precisely found when teachers have mediated between ICT and pupils and the teachers have explicitly fostered these cognitive and metacognitive skills (Burns et al., 2003; De Corte, 1993; Ringstaff & Kelley, 2002; Wenglinsky, 1998). This relates again to the first problem mentioned above.

Despite the value of this previous research, there are several issues related to *what is being measured*. First of all, most of the studies has studied the pupil outcomes independent from contextual or external affecting variables, such as teachers, teaching

styles/practices, school environments, family factors, socio-cultural contexts, and have hardly been set-up in authentic school settings (Selwyin, 2000). Secondly, most studies focus on final pupil outcomes as "products" and measured by test-scores. Little research has focused on the analysis of the actual cognitive "process of learning". Most of the studies reviewed has been carried out using traditional ways of assessment, which do not adequately capture the skills that ICT help to develop (Ringstaff et al., 2002; Welle-Strand & Thune, 2003). These skills are very close to the constructivist perspectives that put these skills at the center of meaningful, contextual and challenging learning environments (Baron & Bruillard, 2003; Law, Lee, & Chow, 2002). Therefore, the assessment - of pupils and teachers in these ICT-based environments - should focus on evaluating the ability to apply the subject knowledge and skills in authentic collaborative tasks. Two elements under this new perspective are underlined: (a) solve problems effectively using the knowledge constructed and (b) explain and defend decisions made in the problem-solving activity. The latter is related to the development of metacognitive skills and thinking about thinking (Bednar, Cunningham, Duffy, & Perry, 1992; Jonassen, 1992). Thirdly, little research has studied the way ICT-developed knowledge and skills are used in non ICT-based contexts. Future research is clearly challenged by these three issues to study the impact on pupil performance due to ICT-use in school (Haertel & Means, 2000; Rumberger, 2000).

Consequently, a third problem is related to *the methodology to measure outcomes of pupils and teachers*. Bearing in mind the above perspectives and additional methodological comments, the following considerations should be taken into account in up-to-date educational technology research: (a) a focus on the impact over time (middle term and long term), (b) studies in naturalistic settings, (c) measurement of the impact on near transfer tasks, (d) control of instructional variables, (e) the use of a variety of measures for assessment, and (f) the use of control groups (Burns et al., 2003; Cox et al., 2004a; Cox et al., 2004b; De Corte, 1993; Haertel et al., 2000; Rumberger, 2000; Spector, 2001; Selwyin, 2000).

Taking into account these three problems related to earlier research about the impact of ICT-based learning environments, this dissertation aimed at researching the effect of an Ecuadorian educational ICT-based initiative, the Innovation of Education in the Santa Elena Peninsula (IEPSE) project.

In view of tackling the methodological critiques found in previous research this dissertation incorporates: measurements taken in natural school settings (regular classrooms), educational innovation delivered by regular teachers (educationally and technologically trained), longitudinal studies of the effects of the ICT-based innovation over a 2 school-year period on pupils and on teachers (by means of video analysis, self-reports and performance tests), and the adoption of qualitative research techniques to corroborate the results of quantitative studies. Moreover, to assess pupils' learning, not only cognitive outcomes (mathematics scores) were measured, but also the levels of cognitive processing while solving collaborative tasks. In addition, the following interaction variables were researched when studying the impact on pupil outcomes: (a) characteristics of the teaching process and the teachers, (b) characteristics of pupils (gender, cognitive style), and (c) perceptions of the pupils about their teachers and their teaching approaches. The impact of the ICT teacher training was observed and studied in regular (non ICT based) science classes.

Even though the thesis incorporates the analysis of mathematics outcomes and science lessons, it is important to stress that this dissertation is not focused on studying effective mathematics teaching nor science teaching. These measurements have been taken to assess pupils' learning outcomes and their teachers' actual teaching.

The general variable model adopted in this dissertation is shown in figure 1. The numbers in the model correspond to the hypotheses and research questions.

Before proceeding with reporting the individual studies and research results, we first present the main research questions, the characteristics of the in-service ICT teacher training, the general design of the studies, and the structure of the dissertation.

<div align="center">Research questions</div>

The dissertation reports the results of seven studies carried out over a period of 2 school years (years 2002-2003). The studies research the impact of the IEPSE project on teachers' teaching and on pupils' learning through the implementation of the ICT in-service teacher training and the successive quasi-experimental treatments of 5th grade pupils. These seven studies focus on the following research questions:

1. Is the content of the IEPSE ICT teacher training programme and its instructional approach in line with international trends in teacher training?

2. Is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?

3. What is the long-term impact of the training programme on the teaching strategies of IEPSE-teachers in their classroom context?

4. What is the impact over time of the IEPSE project - and the subsequent changes in the learning environment - on the actual cognitive processing of the pupils and on the mathematics learning outcomes of 5th grade pupils?

5. Can the results of the quantitative studies of IEPSE be corroborated by adopting qualitative methods?

Figure 1 depicts the variables researched in the different studies and the hypothetical relations between them as they appear in the research questions, with the exception of research questions 1, 2, and 5. The numbers that appear in figure 1 correspond to the hypotheses and research questions.

Figure 1. Variable model and hypotheses of the IEPSE study

aSC: social-constructivist

Table 1 summarizes the relationship between the research questions and the different (clusters of) hypotheses.

Table 1. Research questions and corresponding hypotheses

Research Questions	Hypotheses
1. Is the content of the IEPSE ICT teacher training programme and its instructional approach in line with international trends in teacher training?	Answer to this question is tackled through descriptive and explorative methods.
2. Is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?	Answer to this question is tackled through descriptive and explorative methods.
3. What is the long-term impact of the training programme on the teaching strategies of IEPSE-teachers in their classroom context?	3a. IEPSE teachers have adopted ($3a_1$)/self-reported ($3a_2$) to a higher extent social-constructivist teaching principles in their science classroom practice as compared to non IEPSE-teachers. 3b. IEPSE pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles by their teachers in science classroom practice will be higher as compared to non IEPSE-pupil ratings. 3c. IEPSE teachers have adopted ($3c1$)/self-reported ($3c_2$) to a higher extent in 2003 social constructivist teaching principles as compared to 2002.
4. What is the impact over time of the IEPSE project – and the subsequent changes in the learning environment – on the actual cognitive processing of the pupils and on the mathematics learning outcomes of 5th grade pupils?	4a. IEPSE pupils show higher level of cognitive processing ($4a_1$) / mathematics scores ($4a_2$) as compared to pupils that did not participate in the project. 4b. Pupils' characteristics (cognitive styles and gender) interact with their levels of cognitive processing ($4b_1$) and mathematics scores ($4b_2$). 4c. There is a positive relation between the average perception of a teacher by his/her pupils about the adoption of social-constructivist teaching principles and the level of cognitive processing of his/her pupils ($4c_1$) and mathematics scores of his/her pupils ($4c_2$). 4d. There is a positive relation between pupils' mean levels of cognitive processing and their mathematics scores 4e. IPESE-pupils demonstrate/attain higher level of cognitive processing ($4e_1$)/mathematics scores ($4e_2$) in 2003 as compared to 2002 and as compared to other pupils in the control condition.
5. Can the results of the quantitative studies of IEPSE be corroborated by adopting qualitative methods?	5a. The educational paradigm promoted by the educational authorities in Ecuador is not adopted effectively by teachers or the educational authorities. 5b. The quality of the IEPSE training is in line with up-to date quality indicators of ICT teacher training. 5c. IEPSE teachers and pupils show positive attitudinal differences in comparison to other teachers and pupils that have not participated in the project.

The IEPSE training programme

The innovation of education in the Santa Elena Peninsula project (IEPSE) is an ICT-based educational initiative that has been implemented during the last 5 years by the Ecuadorian university Escuela Superior Politécnica del Litoral (ESPOL). It consists of several components: (a) an in-service teacher training programme, (b) deployment of computer labs with internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and educational support for teachers trained in the programme.

IEPSE teachers were trained to adopt social-constructivist instructional principles in their classrooms while integrating ICT tools into their teaching. According to the constructivist approach learning is active, constructive, intentional, authentic, cooperative, collaborative, conversational and socially negotiated (Bednar et al., 1992; Driscoll, 2000; Jonassen et al., 2003; Schunk, 2004).

Teachers were involved in the design of complex, relevant and contextual tasks that were tackled in a collaborative way by the pupils. These tasks involved the use of mindtools, such as Logo-Microworlds® and Lego Mindstorms®. These tools are considered to be *mindtools*, since they are in line with the definition of Jonassen: (a) the ICT-application can be used to represent knowledge; (b) the experience is generalizable to content in different subjects (in this case mathematics, natural sciences, geography, etc.); (c) it engages the learner in critical thinking about the subject; (d) it develops skills transferable to other subjects; (e) it significantly restructures or amplifies thinking, and (f) the tool is learnable in 2 hours or less (Jonassen, 1996, Jonassen et al., 2003).

Design of the studies

As mentioned above, the dissertation reports the results of seven studies. The first study is a literature review of current international trends in ICT teacher training and teacher training approaches. This study helps to position the IEPSE training curriculum and approach in the context of these trends. Research question 1 is answered through this study.

The second study researches the relevance of the IEPSE content in view of the characteristics of teachers in the Santa Elena Peninsula region. The study is based on a survey aiming to gather information about teacher characteristics, and perceptions of teachers about their ICT-competences and adoption of constructivist teaching strategies. 43 schools and their teachers participated in this study. This second study answers research question 2.

In this paragraph we will describe the sample procedure followed in the subsequent studies. The 43 schools that participated in the first study were selected ad random from the 137 public schools in the Peninsula Region. They were invited to participate in an introductory conference about the IEPSE project. Due to resource limitations, only 20 schools could join in the IEPSE-project. This selection was based on the extent to which schools were able to invest time in the project and whether teachers were able to follow the training linked to the project. 6 teachers were randomly selected from the list of all fifth-grade teachers that teach in these twenty schools (using code assignment). Next, three fifth-grade teachers were selected ad random from the 23 schools that were – yet - not included in the IEPSE-project. But only 2 teachers answered positively to the request to participate in further studies. As a result the eight fifth-grade teachers and their classes (249 pupils in total) participated in studies 3 to 6. The number of pupils varied from study to study due to the research design and for other several reasons e.g., pupils not attending to schools when some tests were taken, pupils that left the schools from one year to the next year, illness, and so forth. It is to be stressed that the sample approach focused on schools and teachers linked/not linked or attending/not attending to the IEPSE programme. We involved the pupils of the classes that were the responsibility of the selected teachers. Table 2 summarizes the number of pupils that participated in each test linked to each study.

Table 2. Number of pupils linked to the different studies of this dissertation

Studies	Test/measurement	*N*
Study 4, study 5 and study 6	CLES - 2003	204
Study 5 and study 6	GEFT	241
Study 5 and study 6	Level of cognitive processing in year 2002 and 2003	64
Study 6	TIMSS 2002	239
	TIMSS 2003	249

The third study researches the impact of IEPSE on the actual teaching practices of primary school teachers. It is based on a quasi-experimental research design, building on a posttest and involving next to an experimental group of teachers, two control groups. Eight fifth-grade teachers and their classes were studied in regular science lessons contexts (non-ICT classes) in year 2002. The study is based on video-analysis of actual teaching practices with the help of an observation form, the Constructivist Teaching Inventory - CTI of Greer (1997); and self-reported teaching strategies gathered through the Constructivist Learning Environment Survey - CLES of Taylor, Fraser & Fisher (1997).

The fourth study is partially a replication of study three. It studies the teachers and pupils that participated in the third study, but now one year later. In addition to the procedures followed in study 3, perceptions of the pupils about the teaching of their teachers were analyzed through the pupils' version of CLES. The focus in this fourth study is on the long-term impact of the IEPSE teacher training programme on the actual teaching approaches of the teachers.

The fifth study focused on the impact of the IEPSE programme on the levels of cognitive processing of pupils. The design is based on a quasi-experimental research set-up, with a pretest-posttest. The study was set up to research the impact over time of IEPSE on the levels of cognitive processing of sixty-four 5th grade pupils (a sub-sample of the original one). Two experimental and one control condition were established in this study. Non ICT based collaborative activities of pupils in the experimental and control conditions were videotaped and analyzed after two and three school years of the project. The collaborative groups had to plan a reunion or trip based on role play. The

analysis scheme of Gunawardena, Lowe & Anderson (1997) was used to code the pupil activities according to levels of cognitive processing. The teaching principles perceived by the pupils (CLES) and its relation to their levels of cognitive processing were included in this study. Cognitive styles as measured with the GEFT test (Witkin et al., 1971), and gender differences were considered as well.

The sixth study mirrors the quasi experimental research design of the fifth study. Pretest and posttest mathematics scores of 202 pupils from two experimental and one control group were analyzed with the TIMSS test (Mullis et al., 1997) for school year 2002 and year 2003. The degree of adoption of social constructivist teaching (CLES) by teachers, cognitive style (GEFT) and gender were included as interaction variables in the analysis of the results. Also the levels of cognitive processing as studied in study 5 were related to the mathematics scores for further analysis.

The seventh study reflects a qualitative research design to corroborate the findings of the above quantitative studies about the impact of IEPSE on pupils and teachers that participated in this project. Focus groups, a Delphi study and the Metaplan® method were used. Five educational leaders with a long and vast educational experience in the Ecuadorian context participated in this study.

<div align="center">Structure of the dissertation</div>

This dissertation is structured in five chapters that present the theoretical rationale of the research, enter into an explanation of the research approaches and procedures, and analyze and discuss sequentially the results obtained from the seven studies. All chapters have been - or are based on papers submitted -for publication in international peer-reviewed journals. They aim to answer the research questions and to test the general hypotheses as presented in table 1. Table 3 provides an overall picture of the seven studies, and the five research questions discussed in the different chapters.

Table 3. Overview of the studies' research questions addressed in the different chapters

	Study 1	Study 2	Study3	Study 4	Study 5	Study 6	Study 7
Chapter 1[a]	Research question 1	Research question 2					
Chapter 2[b]			Research question 3	Research question 3			
Chapter 3[c]				Research question 4	Research question 4		
Chapter 4[d]				Research question 4	Research question 4	Research question 4	
Chapter 5[e]							Research question 5

[a]Partly based on a paper submitted for publication in *International Journal of Educational Development.*
[b]Partly based on a paper submitted for publication in *Teaching and Teacher Education: An International Journal of Research and Studies.*

[c]Partly based on a paper submitted for publication in Educational Technology Research and Development - ETR&D.

[d]Partly based on a paper submitted for publication in Journal of Computer Assisted Learning.

[e]Partly based on a paper submitted for publication in *International Journal of Educational Development.*

Chapter 1 presents the research about the importance of teacher training for the acquisition of ICT-related teaching practices in the classroom and the shift in the educational paradigm needed to exploit the potentialities of ICT. Three research questions are central in this chapter: (1) is the content of the IEPSE ICT teacher training programme in line with international trends?; (2) to what extent is the teacher training approach in line with state-of-the art approaches to the professional development of teachers?; and (3) is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?

In view of answering the first research questions of chapter 1, a theoretical review of international trends in ICT teacher training and approaches to teacher training is presented to position the IEPSE approach. To answer the second research question, a small descriptive study based on a survey for determining characteristics of teachers in the Peninsula region was set up.

Chapter 2 presents a more complete picture of the IEPSE impact on teachers' teaching after two (2000-2002) and three years (2000-2003) of being involved in the training programme. It aims at answering the following research question: What is the long term impact of the IEPSE programme on the teaching strategies adopted by the teachers in their classroom? The following hypotheses regarding our main research question in chapter 2 are tested:

1. IEPSE-teachers have adopted to a higher extent social-constructivist teaching principles in their science classroom practice as compared to non IEPSE-teachers.

2. IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice will be higher as compared to non IEPSE-teacher ratings

3. IEPSE-pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles by their teachers in science classroom practice will be higher as compared to non IEPSE-pupil ratings.

4. IEPSE-teachers have adopted to a higher extent in 2003 social-constructivist teaching principles in their science classroom practice as compared to 2002.

5. IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice in 2003 will be higher as compared to 2002.

In view of answering research question 2, a quasi-experimental study was set up. We analyze the observed and self-reported teaching strategies of primary school teachers that have been involved during 3 years in the IEPSE-programme. Also the perceptions of the pupils about the teaching principles adopted by their teachers are included in this analysis.

Chapter 3 focuses on the impact of the project on the cognitive processing of 5th grade pupils and the extent to which this impact is influenced by the adoption level of social constructivist instructional principles by their teachers. This brings us to the central research question of chapter 3: What is the impact over time of the IEPSE project - and the subsequent changes in the learning environment - on the actual cognitive processing of the pupils? The following hypotheses were tested to find an answer to the general research question of this chapter:

1. IEPSE-pupils show higher mean levels of cognitive processing compared to pupils that did not participate in the Logo-sessions.

2. Pupils characteristics (cognitive style and gender) interact with the levels of cognitive processing demonstrated during the group activities.

3. There is a positive relation between the average perception of the pupils about their teachers' adoption of social-constructivist teaching principles and the level of cognitive processing of the pupils.

4. IEPSE-Pupils demonstrate higher levels of cognitive processing in 2003 as compared to 2002.

In view of testing these hypotheses a quasi-experimental research was set up. Pupils were observed and analyzed while working collaboratively on a problem-solving task. The study analyses the differences in the levels of cognitive processing demonstrated by pupils after two and three years of being involved in the IEPSE project. Individual differences of pupils are studied as well. In this chapter the perceptions of pupils related to degree of adoption of teaching strategies are also incorporated.

Chapter 4 addresses the impact of the IEPSE project on the mathematics scores demonstrated by the 5th grade pupils and the extent to which the impact is influenced by the degree of adoption of social constructivist instructional principles by their teachers. This brings us to the general research question of chapter 4: What is the impact over time of the IEPSE project - the use of the Logo-mindtools and the adoption of new teaching practices - on the mathematics learning outcomes of 5th grade pupils? The following hypotheses were tested to answer the central research question of this chapter:

1. IEPSE-pupils attain higher mathematics scores compared to pupils that did not participate in the experimental programme.
2. Pupils' characteristics (cognitive styles and gender) interact with their mathematics scores.
3. There is a positive relation between the average perception of a teacher by his/her pupils about the adoption of social-constructivist teaching principles and the mathematics scores of his/her pupils.
4. There is a positive relation between pupils' mean levels of cognitive processing and their mathematics scores.
5. IEPSE-pupils attain in 2003 higher mathematics scores as compared to their scores in 2002 and as compared to scores of pupils in the control condition.

In view of testing these hypotheses, a quasi-experimental design was implemented. A mathematics test, a cognitive style test, a non-participant observation instrument, and questionnaires were used to test these set of hypotheses. The study analyzes the differences in the mathematics scores attained by pupils after two and three years of being involved in the IEPSE project. In this chapter the perceptions of pupils related to the levels of adoption of teaching strategies are included as well.

Finally, chapter 5 focuses on alternative ways of studying the impact of the IEPSE projects on pupils and teachers. Although the research approach followed in chapters 1 to 4 included already to a certain extent multiple ways of measuring the same constructs, qualitative approaches might be helpful to present additional information. Chapter 5 aims at answering the following research question: Can the results of the quantitative studies about IEPSE be corroborated by adopting qualitative methods? The following working hypotheses were tested to help in answering the main research question of this chapter:

1. The educational paradigm promoted by the educational authorities in Ecuador is based on social constructivist principles.

2. The educational paradigm is not adopted effectively by teachers, or the educational authorities. Typical indicators are:

   a. Lack of knowledge about the concrete meaning of the paradigm and a lack of experience in putting it into practice.

   b. The majority of public Ecuadorian teachers do not promote typical social constructivist approaches such as team-work, problem-solving skills.

   c. There is a general demand for reform in Ecuadorian education with a focus upon changes in didactical approaches that are in line with social constructivism.

3. Information and Communication Technologies are seen by teachers and educational authorities as a rich tool to foster teaching and learning in line with the social constructivist paradigm. But, there is a lack of resources and a lack of teacher training to adopt and implement the adequate teaching and learning strategies.

4. The quality of the teacher training offered by the IEPSE is in line with up-to-date quality indicators of ICT teacher training.

5. The teachers that are members of the IEPSE network show attitudinal differences in comparison to other public primary-school teachers: such as high responsibility, high self-esteem and leadership.

6. The pupils that have been taught by teachers receiving IEPSE-teacher training, show also high self-esteem, command in expressing their ideas or projects and in managing the educational environment they are used to work on. The pupils show happiness when presenting their accomplishments.

The study in this chapter is based on group interviews, focus groups, a Delphi study and the Metaplan® method. These qualitative research methods were selected to gather rich and large collections of additional information. Individual input of participants preceded the focus group activities and the Delphi technique to discuss in depth the individual input. These techniques are used to take advantage of participants' creativity as well as facilitating the effect of group involvement and group interaction.

The general discussion and conclusions section of this dissertation will pull together the findings of the previous chapters. All research questions will be analyzed from a more general and integrated perspective. Finally, limitations and implications of this study, as well as ideas for future research will be put forward.

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Chapter 1

An Ecuadorian ICT teacher training programme: positioning the training content and training approach[∗]

Abstract

The present article studies the nature and training programme of an Ecuadorian teacher training programme focusing on the integrated educational use of information and communication technologies (ICT). An international review grounds the state-of-the-art nature of the ICT teacher training content of the programme. Second, a discussion of the constructivist training approach adopted in the programme helps to position the programme in state-of-the art approaches towards teacher training. Thirdly, a descriptive study of the characteristics of Ecuadorian teachers, underscores the need for a training programme, focusing on competences, such as pursued with IEPSE. A discussion of the findings, and implications and ideas for future research are presented.

Introduction and problem statement

During the last two decades the development and capabilities of Information and Communication Technologies (ICT) have transformed the ways we communicate, live, work, play and learn. This transformation has caused industrial society to become the "information society" or "knowledge society" (Kozma, 2003). As a result, the creative features of ICT and its applications enable people to increase the quality of life through the improvement of teaching and learning. That is why ICT is considered a "transformative tool" (ETS, 2002) and also a *mindtool*. Jonassen, Howland, Moore, & Marra (2003) state that in the context of education, these new technologies might function as "intellectual tool kits" and as "intellectual partners" that allow the citizen of the third millennium to create new knowledge from discrete bits of content, individually or together, through a variety of resources (Kirschner & Wopereis, 2003; Niemi, 2003).

Becoming competent members of the knowledge society implies the acquisition of "productive skills," problem-solving skills, independent learning skills, and lifelong

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[∗] Partly based on a paper submitted for publication in *International Journal of Educational Development*

learning attitudes (Law & Plomp, 2003). Only the integration of ICT into education can convert students into "productive knowledge workers" (Pelgrum, 2001). Teachers play a major part in this educational reform, and the importance of their role has major implications for teacher training. Knierzinger, Røsvick, & Schmidt (2002) consider adequate teacher training as the most essential factor in the integration of ICT into education.

The present article centers on the content and training approach adopted in an Ecuadorian teacher training programme, the Innovation of Education in the Santa Elena Peninsula (IEPSE). Three key questions are put forward: (a) Is the content of the IEPSE ICT teacher training programme in line with international trends?; (b) to what extent is the teacher training approach in line with state-of-the art approaches to the professional development of teachers? and (c) is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?

The first part of this article concentrates on answering the first research question, based, on a review of international trends in determining the content of an ICT teacher training. The IEPSE teacher-training programme is examined and contrasted against these international trends. The second part of the article focuses on the second research question. The IEPSE-training approach is positioned in the context of the (social) constructivist framework and current approaches towards teacher training. The third part of the article reports the results of a survey about the profile of primary teachers in coastal Ecuador. The descriptive results are expected to ground the need for the ICT teacher training programme as it has been put forward in the second part of the article. The paper concludes with a discussion of the findings, research implications and ideas for future research.

Approaches to the development of ICT teacher training programmes

Identification of different approaches

There is worldwide governmental interest and investment in ICT education. As is clear from overviews by Plomp, Anderson, Law, & Quale (2003) and Pelgrum (2001), who analyzed the ICT policies and practices of more than 30 countries around the world. Plomp et al. found master plans or policies to integrate ICT into education in the

majority of the countries. A variety of methodologies towards ICT teacher training programmes can be observed in these policies.

A first and dominant design approach is based on a predefined set of national standards or competences that direct the ICT teacher training curricula. A typical example is the National Education Technology Standards (NETS) published by the International Society for Technology in Education (ISTE) that presents the ICT standards for all teachers in the USA (ISTE, 2004). In the UK, since 1999, every qualified teacher needs to demonstrate mastery of ICT competences that reflect the compulsory standards in order to receive Qualified Teacher Status (QTS). The Teacher Training Agency (TTA) in the UK has developed ICT skills tests and training to guide teachers. In Australia, each state has developed or is developing competence sets related to the use of ICT in education; characteristic examples are the framework of Martin (2001) and the set of professional standards of Queensland State (Education Queensland, 2002). In Finland a nationwide information society strategy forces teachers to develop knowledge and skills needed to reform pedagogical practices. The focus is oriented to teaching and learning collaboratively, networked and team work and the use of ICT as a mindtool (Niemi, 2003). Internationally, a set of ICT-related competences is recognized by the UNESCO Institute for Information Technologies in Education (ITTE) as part of an elementary ICT curriculum for teacher training (Knierzinger, Røsvick, & Schmidt, 2002).

An alternative teacher training design is based on benchmarks. For example, Kirschner & Davies (2003) present a set of six benchmarks after analyzing 26 case studies of "exemplary practice" of ICT integration in teacher training in 6 different countries (The Netherlands, the USA, England, Finland, Australia and Northern Ireland). Kirschner et al. (2003) stress that the incorporation of these benchmarks into teacher training is not only "talking about" related constructivist thinking and pedagogy, but also about adopting and modeling these practices in the actual teacher training sessions.

A third approach is presented by Kozma & McGhee (2003) and Cox et al. (2004), who identify innovative exemplary ICT practices of teachers. Although the results of this exercise do not point to what competences teachers have to adopt, they suggest characteristics of innovative ICT-based teaching practices. These innovative practices are recommended as part of training frameworks.

A final approach is based on expert opinions about the content and approach of teacher training. A clear example is proposed by the Society for Information Technologies and Teacher in Education (SITE) in the AMES white paper. This white paper is a statement of basic principles and suggested actions to improve the preparation of American teachers to use technology in the classroom (SITE, 2004).

A descriptive analysis of ICT competences put forward in teacher training

The different design approaches reviewed in this paper consider a variety of ICT teacher training curricula. A descriptive analysis of these teacher training curricula competences put forward is presented in appendix 1. Nine clusters of competences are common to most design approaches, and resulted from this analysis.

A. Basic ICT and productivity skills
B. Using ICT as a mindtool and for cooperation/communication.
C. Selection, assessment and evaluation of ICT products.
D. Adoption of a variety of instructional/pedagogical strategies and ICT resources for learning, especially those that promote constructivist strategies.
E. Design and production of learning materials with ICT.
F. Evaluation of teaching and learning approaches with ICT.
G. Teaching through or with ICT to enhance learning in different settings.
H. Student-centered teaching considering learning styles supported by ICT.
I. Social and ethical issues of ICT use.

Not every competence cluster appears in every example in appendix 1. For instance, competences related to the use of ICT for assessment and evaluation are not present in the approaches of Education Queensland (2002) or Kozma and McGhee (2003). Similarly, the social implications of ICT use are not considered in the work of Cox et al. (2004). There is a large degree of consistency in the cluster content between the categories in appendix 1, but also some remarkable differences. For instance, ICT as a mindtool is absent in the majority of the approaches.

A comparison of the cluster of competences put forward with the competences of the IEPSE teacher training programme indicates that the IEPSE programme encompasses 7 out of the 9 clusters of competences found in international approaches to ICT teacher training (Appendix 1 includes too the IEPSE competences). A description of the cluster of competences put forward with the IEPSE training is included in

appendix 2. This comparison helps us to give an answer to the first research question by stating that the competences pursued by the IEPSE ICT teacher training programme mirror the –internationally recognized- standards, benchmarks and best practices of ICT effective teaching. The answer to the second research question will also be informative in relation to this first question. As will become clear from the next part of this article, the content of a teacher training programme is also partly reflected in the way the training has been set up.

<p style="text-align:center">The IEPSE teacher training programme in relation to state-of-the art approaches towards the professional development of teachers</p>

<p style="text-align:center">*ICT-use and emerging pedagogies*</p>

An analysis of the competences described in appendix 1 reveals that a large number of them refer to innovative instructional conceptions that are linked to integrated ICT-use. According to these new conceptions, pupils work in small groups; work at their own pace; reflect on their own work; engage in creative and productive learning and problem solving; and, are guided by their teachers (see Law & Plomp, 2003; Pelgrum, 2001). These activities are closely linked to (social) constructivist approaches to learning and instruction but also to up-to-date or emerging approaches towards teacher training. This introduces the second research question put forward in this article about the way the IEPSE teacher training programme was organized. To answer this question we review – briefly- the literature about current teacher training. The trends, resulting from this review, will be used to examine the concrete IEPSE training methods.

<p style="text-align:center">*Constructivism in teacher training approaches*</p>

In the recent decades, the constructivist concept is a pervasive feature claimed to be part of the design of pre-service and in-service teacher training programmes (Davis, 2003; Hernández-Ramos & Giancarlo, 2004; Linek, Fleener, Fazio, Reine, & Klakamp, 2003; Smith & Sutherland, 2003; Tan, Hu, Wong, & Wettasinghe, 2003). Reviewing the literature, it becomes clear that constructivist position is mirrored in approaches followed by contemporary teaching training and/or professional development programmes. In other words, the teacher training approaches are in large set up in the

way they expect teachers to behave in their own later (constructivist) instructional practice. The general constructivist conceptual base is operationalized in terms of teacher training approaches.

According to Clark & Peterson (1986) teachers constantly think about what is happening in their classrooms and as a result make many nontrivial decisions. However, this thinking/reflective process yields different results depending on the level of expertise of the teacher e.g., the performance of teachers in a beginners stage is not equal to the ones in the experts stage (Berliner, 2001). Therefore, there is a need to structure experiences for pre-service and in-service teachers that facilitate the development of expertise. One way –stressed in current literature about teacher training- of targeting this need is through *reflective practice.* Teachers are engaged in teaching activities; observe their own or the practice of others; reflect upon what is observed; reflect upon the experiences, beliefs, and instructional decisions; discuss these observations with one another and experts and discover multiple perspectives (Jay & Johnson, 2002; Kroll, 2004; Long, 2004; McCombs, 2003; O'Sullivan, 2002; Reid & O'Donoghue, 2004; Richardson, 2004).

Reflective practice is also complemented or empowered by involving teachers in training models based on *collaborative inquiry* and/or *communities of learners/practice* (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004; Clement & Vandenberghe, 2001; Richardson & Placier, 2001). Teachers participating in a community of learners encounter learning contexts that encourage and recognize the importance of thinking time, and emphasize the centrality of social interaction and multiple perspectives in the thinking process (Smith et al., 2003). According to Lave & Wenger (1991), when teachers participate in these communities, their participation gradually shifts from a peripheral to an active increasing participation that is usually unintentional rather than deliberate. These cooperative and reflective learning opportunities are linked to the social-constructivist theory, in which learners actively and cooperatively construct knowledge (Vygotsky, 1978). Partnerships between university faculty, teams of pre-service teachers, and practicing teachers help the promotion of communities of learners and practices. These partnerships for instance, involve a number of partner schools that work with mentor teachers –advised/supervised by teacher educators from universities- who, along with teacher students innovate and reflect about teaching (for examples see Barnhart, 2001; Beckett, Wetzel, Buss, Chisholm, & Midobuche, 2001; Davis, 2003; Hernández-Ramos et al., 2004).

The involvement of teachers in the communities results in situated, meaningful and contextualized learning, because they can link their teaching practice to the real context in which their teaching takes place. *Situated learning* occurs when knowledge is presented in settings and applications that would normally involve that knowledge (Lave & Wenger, 1991). In a situated learning environment, student teachers are the center of the learning process. They are expected to interact with: content, contexts, situations, values, beliefs, and their community –with other student teachers and/or with experts solving problems related to the content (Brown, Collins, & Duguid, 1989). Herrington and Oliver (1999), characterize a situated learning framework –for teacher training- as follows: an authentic context, complex authentic activities; multiple perspectives; expert performances; coaching and scaffolding; opportunities for collaboration, reflection and articulation, and authentic assessment. Generally, these activities are based on complex issues related to real context, and are associated to scaffolding provision to enable novices to operate meaningfully in such realistic environments (Young, 1993; de Jager, Reezigt, & Creemers, 2002). *Cognitive apprenticeship* training models incorporate situated learning as a key approach and it is a term commonly linked to others as *coaching, scaffolding* and *mentoring* that are closely related again to the social-constructivist approach of Vygotsky in view of reaching the zone of proximate development (Harvey, 1999; Hudson, 2004; Kaste, 2004).

The pre-service and in-service training approaches described above can be considered as based on a constructivist position, because they promote learning opportunities for inquiry, discovery, or self-examination and self-reflection; they help teacher students and in-service teachers to deconstruct their own prior knowledge, to comprehend how these understandings evolved, to consider alternate or multiple views that may be more useful in their actual teaching. These learning opportunities acknowledge individual participation and knowledge construction; but at the same time places peer-interaction in collaborative setting as important as the individual ones.

Actual use of new pedagogies as reflected in ICT practices

Despite the influences of constructivism in ICT-based learning and teacher training approaches, empirical evidence about the development of related competences by teachers reflects a less optimistic picture. Research concludes that ICT is being

adopted by teachers, but not in the line with the new pedagogy put forward and at a much slower pace than expected (Becker, 2001; Cuban, 2001; Myhre, 1998). Teachers use the technology to replicate and optimize existing instructional approaches that is, teacher-centered approaches (Cox et al., 2004). A number of reasons have been put forward to account for the weak adoption of innovative ICT-related instructional strategies: teachers need to feel mastery of ICT (confidence, control), they need to know the potential of ICT (ICT uses and effectiveness); they have to have access to resources and opportunities to choose from a variety of ICT tools; they need to get technical and social support, and opportunities to explore ICT-based instructional practices (Cox et al., 2004; Dawes, 1999; Pedersen & Liu, 2003). These previous remarks are important in view of the implementation of teacher training programmes. In addition another indicator of ICT-adoption relates more to the school policy and culture than teachers' needs. Schools in which teachers, school administrators and communities are linked through school learning activities and out-of school learning contexts demonstrate higher levels of ICT adoption in schools (Demetriadis et al., 2003; Tearle, 2003).

The IEPSE: an Ecuadorian in-service ICT teacher-training programme

Building on the review of current trends in teacher training, we can study the way this has been established in the IEPSE-project. First, we present the educational and political context in which the project was set up. Next, we discuss in detail the concrete training design characteristics.

Ecuador lacks an updated educational policy. The last educational reform dates from 1992 and does not include ICT as a catalyst to promote education and educational change. Although Ecuador was the second Latin American country to have access to the Internet, current societal indicators show that the country is below the average of Andean and South American countries in regard to telecommunication and computational infrastructures (TNC, 2002). Only in 2002 was a National Agenda for Connectivity (NAC) set to articulate policies, strategies, projects and programmes. The NAC incorporated five strategic areas to be developed: access infrastructure, tele-education, tele-health, on-line government, and e-commerce. The NAC presented at that time and even today a challenge for the country because the government has been coping with social, political and economic problems. A critical factor for developing the NAC strategic areas has been the lack of a public policy that helps to develop ICT. The

educational reform of 1992 did promote awareness and adoption of social-constructivist teaching strategies in Ecuadorian education, but teacher education in Ecuador has hardly been able to implement these policy guidelines. Teacher professional development is weak in content because "there are gaps, the curriculum does not respond to the needs of the current society and the infrastructure and equipment do not offer the required conditions to foster good teacher education" (MEC, 2002, Formación Docente). In view of the need for a comprehensive ICT teacher training, the Information Technology Center of the Escuela Superior Politécnica del Litoral (ESPOL) designed and implemented the IEPSE project in 2000. The direct aim was to develop key ICT skills in public primary school teachers in rural and urban marginal regions in the Santa Elena Peninsula Region. The indirect aim of the programme was to foster ICT-based learning skills in pupils of the coastal region. The project started in 20 rural primary schools in the Peninsula of Santa Elena and involved 40 trained teachers and nearly 8,000 pupils from first to sixth grade (6-11 years old). Currently, more than 43 schools are part of the IEPSE network, and more than 10,000 pupils are involved. The IEPSE project has four main components: (a) an in-service teacher training programme, (b) the deployment of computer labs with internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and instructional support for teachers trained in the programme. The programme integrates ICT as a tool and as support for the teaching and learning process.

The IEPSE teacher training programme was conceived as a set of workshops that emphasizes on the development of technical and didactical competences of in-service teachers. The IEPSE training included a series of 8 intensive workshops - meetings of 8 hours every day for one week, 320 hours in total. These workshops were developed along 2 years since May 2000. The workshops were held in the Peninsula region and 40 teachers from 20 different primary schools attended to the training together. Teachers had time-slots of two to four weeks -between each workshop- to assimilate and reflect on the newly built knowledge, and to put into practice new teaching skills. The workshops can be characterized as follows:

- Meaningful learning tasks. The tasks related to workshops were linked to a curriculum-based lesson, or unit of the student's choice, or a curriculum-based topic. This feature helped to guarantee that the unit/topic would be directly relevant for their actual classroom practice. Teachers were asked to present didactical problems in the classroom and try to find solutions through the

incorporation of ICT or alternative teaching-learning strategies. This characteristic has been found as important when meaningful and situated learning is pursued (Clement et al., 2001).

- Co-teaching workshops. The workshops were based on a co-teaching model by the teacher-trainer team of IEPSE. Co-teaching was expected to encourage in-service teachers to work collaboratively in their classrooms (Hernández-Ramos et al., 2004).

- Hands-on experience workshops. The workshops focused on hands-on experience with hardware, instructional software (Logo Microworlds® and Lego Mindstorms®), and teaching strategies.

- Reflective learning/teaching. During the workshop the IEPSE team offered at the beginning and at the end of each day opportunities to reflect at the individual and group level about the strategies followed by the trainer team, about the learning experience, and the usefulness of the content and processes learned during this day. In addition, the training included observation of classroom activities prepared by experts and teachers involved in the programme, and reflection based on these observations.

- Collaborative work. The workshops related tasks were developed in groups integrated by teachers from the same school. Teachers participating in this way were expected to rely on one another in developing technological skills and to present projects linked to their schools (Gonzales, Picket, Hupert, & Martin, 2002).

- Coaching teacher training team. The IEPSE team put efforts in demonstrating the constructivist paradigm, in giving feedback, and in coaching follow-up activities. In addition, the IEPSE programme also provided face-to-face tutoring to the trained teachers along the 2-year period. Technological and didactical support teams visited teachers (once every 2 to 3 weeks, at least 10 visits were performed during one school year) in the Peninsula region to help them in tasks and problems that appeared in their classroom practice. These visits were based on scenarios/blueprints, which helped the support team to guarantee that the approach followed in the visits were comparable in the different schools. These support visits were also used to meet teacher groups to analyze critically teachers' teaching using ICT at an individual and group level, promoting

communities of learners and communities of practices. This type of follow-up and supportive features of a teacher training programme has been found decisive to achieve professional development and in the successful adoption of teaching strategies (Bitan-Friedlander, Dreyfus, & Milgrom, 2004).

- From basic to complex. The difficulty level of the workshops increased progressively; for instance, regarding technical contents, teachers learned initially how to use a mouse, a keyboard, and so forth; next, they learned how to use e-mail, discussion forums; and later they designed classroom projects using Lego-Mindstorms®, Logo Microworlds®, and the Internet. Similarly, at the start of the educational workshops contents were related to the role of the teacher as a coach of the learning process, and gradually their contents focused on instructional design or the implementation and evaluation of educational projects at the micro-level.

- Integrating technological and didactical competences. Although the group of competences developed in IEPSE trained teachers were categorized as technical and didactical, the tasks and activities of the technical workshops were closely related to the didactical ones and vice-versa; for instance, the educational projects -designed by the teachers- were sent via e-mail to their tutors and they received feedback also using the same means.

Coming to a conclusion about the nature of the IEPSE teacher training approach

To answer the second research question, we proposed to mirror both the characteristics of contemporary teacher training approaches and the concrete design of the IEPSE training. The description in the former paragraphs underpins by large the constructivist nature of the teacher training; strategies that are found in present-day trends in training approaches about pre-service and in-service training of teachers are also found in the IEPSE programme. A strong component of the training was the actual demonstration and adoption of the social constructivist paradigm. Appendix 2 helps us to substantiate this conclusion by linking the teacher training approach to the competences, listed in appendix 1. We conclude stating that IEPSE training approach is in line with the state-of-the art approaches to the professional development of teachers.

The training needs of Ecuadorian teachers: results of a survey

Research design

The third research question in this article centers on the relevance of the IEPSE teacher-training programme in view of the educational needs of teachers in the Santa Elena Peninsula in Ecuador. A survey, based on a questionnaire, was organized to gather information about teacher characteristics, and perceptions of teachers about their ICT-competences and adoption of constructivist teaching strategies. This survey was set up closely in line with the launching of the IEPSE-project. The survey was expected to help the project team to gather basic evidence and information about the teachers involved in the region; their ICT-related skills and needs; and, their basic approach towards learning and instruction. It has to be stressed that no such baseline information was available about the teachers in the Peninsula region.

A sample of 40 schools was randomly selected from the total number of public primary schools in the Peninsula region (*N*=137). The schools in the sample reflected characteristics shared by all schools in the region. All of them depend on government assignations to operate, 93% of the school posses a good physical infrastructure to host computers laboratories. The average number of pupils per school is 237. The number of staff in primary school is 9, including the school administrator (DEG, 2000; DEG, 2003). Forty schools were invited to participate in the study. To anticipate non-response, 10 extra schools were selected from the school population and were also invited to participate in the study. Forty-three schools answered to the invitation and 337 surveys -corresponding to the total number of teachers of these schools- were gathered.

Research variables and research instrument

The questionnaire consisted of items focusing on information about teacher characteristics (age, years of teaching experience, educational background) and items focusing on two competences related to teaching and ICT-use. The ICT-related items gathered information about experience in the use of productivity packages, such as word processors, spreadsheets, presentation software and the Internet. Next, items focused on frequency of ICT use in the classroom, the dominant teaching approach adopted in the classroom (adoption of a traditional versus a constructivist teaching approach),

participation in teacher training and experience as a teacher trainer. Two open ended-questions gave teachers the opportunity to add additional information in relation to the responses to the other survey items. The instrument was pilot tested involving a small sample of teachers from the Peninsula region to ensure its clarity and legibility. These teachers did not participate in the further study.

Procedure

Each school received a written invitation to participate in study at the start of a launching session of the IEPSE project in 2000. An independent organization administered the instrument, being trained in the administration of this type of instruments. The filled-out instruments were passed to members of the Information Technology Center at ESPOL to be coded and analyzed. The answers to the close-ended questions were coded. The answers to the open-ended questions did not add new information to the one obtained by means of the closed-ended items. Considering the focus of the survey – obtaining a baseline about teacher characteristics – the analysis approach was limited to reporting descriptive statistics.

Results

Table 1 presents the percentages as they relate to the answering categories of the different items of the questionnaire. We can outline the following profile of teachers from the Peninsula region. They are mainly female over 45 years in age. They have more than 15 years of teaching experience and they are paid by the government. The majority is not near to retirement. Regarding the educational profile of teachers, more than 70% of the teachers of the study have a diploma for teaching in primary education, which is granted by a vocational institute or university. The majority of teachers has not acquired a post-graduate diploma. Moreover, the type of continuing education they attend to is mostly related to the educational reform of 1992, promoted by the Ministry of Education. Finally, these teachers have hardly been involved as trainers of other teachers.

Regarding teachers' ICT and Internet skills, the teachers of the study reported to have a very low to zero level of technical ICT competences. They report that they promote constructivist teaching and learning approaches in their classrooms or a mix of

traditional and constructivist approaches. In addition, teachers highly agree that ICT is relevant to use in the teaching-learning process. Based on these descriptive results we can present the tentative answer that the IEPSE teacher training is –at the content level- in line with the needs of the teachers in the Peninsula region. Teachers consider instructional ICT-use to be relevant in their classes; they report a clear or mixed orientation towards constructivist approaches. But, they are very clear about their lack of technical ICT-skills.

Discussion

The purpose of this paper was to answer the following questions: (a) is the content of the IEPSE ICT teacher training programme in line with international trends?; (b) to what extent is the teacher training approach in line with state-of-the art approaches to the professional development of teachers? and (c) is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?

In view of answering the first question, the researchers performed a literature review to identify current international trends in ICT teacher education programmes and teacher training approaches. This literature review resulted in a descriptive analysis of different design approaches to teacher training curricula, including the IEPSE ICT training. Nine clusters of competences resulted from this descriptive analysis. We found that the IEPSE training encompasses 7 out of the 9 clusters identified in appendix 1.

In view of answering the second research, the IEPSE training –based on the (social) constructivist approach towards learning and instruction- was mirrored to current trends in teacher training approaches to teacher training in a more general basis, by building on reflective teaching, collaborative practices and the use of learning communities.

In view of answering research question 3, a limited survey helped to get insight into the profile of public primary school teachers in the Santa Elena Peninsula and a baseline about their educational needs. In general, these teachers are aware about their low ICT-skills; they found ICT use relevant in the teaching-learning process; the majority is not recently involved in attending to teacher training (49%), or only attends to seminars about the educational reform of 1992. These results confirm the outcomes

of the study of Mera & Zurita (2002), who detected similar teachers' characteristics such as average age, educational training background, and poor ICT skills in teachers

Table 1. Overview of responses to the questionnaire items (*N*=337)

Teacher characteristics	Percentage	Categories
Gender	59.0	Female
	41.0	Male
Age	19.6	Young (< 36 years)
	34.8	Medium Age (36-45 years)
	45.5	Mature teachers > 45 years
Years of teaching experience	18.0	Less (< 7 years)
	24.3	Medium (7-15 years)
	57.8	More (> 16 years)
Years before retirement	16.6	Does not apply (paid by NGO's)
	24.8	Very near (< 6 years)
	20.2	Next decade (7-12 years)
	55.0	Far (> 13 years)
Sources of teacher's payment	83.0	Paid by Government
	17.0	Paid by NGO's, communities, etc.
Teacher training background	14.2	No teacher training background
	72.3	Diploma for teaching in primary education obtained in vocational institutions or Universities
	13.3	Diploma for teaching secondary education obtained in Universities
	0.3	Technical and educational background in vocational institutions
Type of post-graduate studies	99.7	Does not posses post-graduate diploma
	0.3	Special certificate in educational leadership
Productivity ICT-skills	88.7	Zero or Low level
	8.9	Medium level
	2.4	High level
Internet skills	98.2	Zero or Low level
	1.8	Medium level
Teaching strategy most frequently promoted in the classroom	49.0	Mix of traditional and constructivist teaching approach
	41.0	Constructivist teaching approach
	5.9	Traditional approach
	3.9	Other
Agreement regarding the relevance of ICT use in teaching – learning process	90.7	Total agreement
	7.7	Partial agreement
	0.3	Partial disagreement
	1.2	Total disagreement
Recently attended to teacher training (during the last 2 years)	49.0	No training
	51.0	Seminars about the educational reform initiated in year 1992
Involvement as a trainer	98.5	No tutor or trainer involvement
	1.5	Yes, involvement as facilitator of seminars sponsored by the Ministry of Education

from the Guayas province, the province to which the Santa Elena Peninsula belongs. Therefore, we feel confident to conclude that the ICT-competences put forward in the IEPSE teacher training programme might suit the training needs of teachers in the Peninsula region.

Regarding teaching approaches promoted by teachers, the majority of teachers promotes a *curious-mix* of teaching strategies –constructivist and traditional strategies- (49%), whereas an important group of teachers (41%) promotes the constructivist teaching principles. On one hand, this finding encourages the researchers because the instructional orientation in the IEPSE teacher training emphasizes the use of constructivist teaching principles. On the other hand, the same finding alerts the researchers to observe caution. Because a large portion of the teachers report a mix in the teaching approaches they promote, the IPESE training might also differ from the instructional orientation of the teachers in the training. Constructivist and traditional approaches are based on different epistemologies and therefore promote different type of activities in the classroom (Bednar, Cunningham, Duffy, & Perry, 1992; Burton, Moore, & Magliaro, 2004; Duffy & Cunningham, 1996). The survey about teaching approaches promoted by teachers in the Peninsula region can not be contrasted with other studies due to the lack of evaluation studies regarding this topic.

From a methodological perspective, some weaknesses of the study can be put forward. A first weakness is related to the use of a questionnaire and the fact that the study is based on self-reporting by the teachers. No other data have been gathered that might have helped to confirm the personal ratings or answers of the teachers e.g., based on the analysis of video recordings of samples of teaching activities of the teachers. A second weakness is the restricted analysis approach of the questionnaire answers. Further research should incorporate these alternative methods to contrast the findings of this study.

General conclusion

Despite the methodological limitations of the study and the descriptive nature of the research presented in this article, we feel confident that the study has resulted in a number of useful outcomes. First, as a result of the analysis of international trends in teacher education, a comprehensive set of nine competences -commonly found in ICT-teacher education curricula- has been set down. The content of the IEPSE training fits

into this framework. Second, the analysis of teacher training approaches has made clear that the specific instructional approach of the IEPSE teacher training is in line with current international trends. Third, a baseline about the technical and instructional characteristics of teachers in the Peninsula region is now available. As we stated above, follow-up studies will be needed to document with methodological rigor the actual adoption of teaching strategies by the teachers as reflected in their current teaching practices. This richer baseline will be a better starting point to study the impact of the IEPSE teacher training both on teachers and their pupils. These studies are foreseen to be set up in the near future.

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Appendix 1. Teachers' competences in the information society

	Competences/Standards	A1	A2	B	C	D	E	F	G	H	I
Benchmarks (Kirschner and Davies, 2003)	Demonstrate personal ICT competencies.	X	X								
	Use ICT as mindtools for collab./coop. on pedagogical projects.			X							
	Manage a range of educational/pedagogical paradigms which make use of ICT.					X		X		X	
	Master a range of assessment paradigms which make use of ICT.				X						
	Use ICT as a tool for teaching.						X		X		
	Consider the social aspects of ICT use in Education										X
Competence Standards (Martin, 2001)	Apply personal knowledge in evaluating instructional resources and learning technologies (ICT) for comprehensiveness, accuracy and usefulness.				X	X					
	Use a range of instructional resources and learning technologies within and across learning experiences.				X	X		X			
	Encourage students to select and use appropriate instructional resources and learning technologies to enhance thinking.							X			
	Engage the wider community as a resource for learning.					X					
	Utilize the whole school as an environment to enhance student learning.					X					
	Implement learning experiences to promote the development of student skills in the use of educational technology.						X				
	Link use of technology with attainment of planned learning outcomes.						X	X			
	Provide opportunities for students to use technology for a variety of purposes.								X	X	
	Ensure students have equitable access to educational technology.										X
	Adjust use of technology to cater for diversity in learning styles and needs.								X	X	
	Demonstrate ICT basic and productivity skills, and Internet and e-mail skills.[a]	X	X								
Queensland Education (2002)	Determine students' learning needs in relation to the use of available ICT.									X	X
	Select learning strategies and resources based on the use of ICT to cater for students' learning needs and styles.					X				X	
	Create learning experiences in which students actively use ICT to organise, research, interpret, analyse, communicate and represent knowledge.						X		X	X	
	Evaluate the effectiveness of teaching and learning approaches based on the use of ICT.							X			
	Use ICT tools to access and manage information on student learning.							X			
	Demonstrate ICT basic and productivity skills, and Internet and e-mail skills.[a]	X	X								

Notes. Competence A1: Demonstrate ICT Basic Skills, Competence A2: Demonstrate ICT Productivity skills, Competence B: Use ICT as mindtools and for cooperation/communication, Competence C: Select, assess and evaluate ICT products, Competence D: Use a variety of instructional/pedagogical strategies and ICT- resources for learning, Competence E: Design and produce learning materials with ICT, Competence F: Evaluate teaching and learning approaches with ICT, Competence G: Teach through/with ICT to enhance learning, Competence H: Apply Student-centered approach for teaching considering learning styles supported by ICT, Competence I: Manage social ethical issues with ICT.

[a] Not explicitly mentioned but included in this table as a key requisite to develop other competences.

Appendix 1. Teachers' competences in the information society (cont.)

	Competences/Standards	A1	A2	B	C	D	E	F	G	H	I
NETS (2002)	Demonstrate a sound understanding of technology operations and concepts.	X									
	Plan and design effective learning environments and experiences supported by technology.				X		X				
	Implement curriculum plans, which include methods and strategies for applying technology to maximize student learning.					X	X			X	
	Apply technology to facilitate a variety of effective assessment and evaluation strategies.							X			
	Use technology to enhance teachers' productivity and professional practice.		X						X		
	Understand the social, ethical, legal, and human issues surrounding the use of technology in PK-12 schools and apply those principles in practice.										X
TTA (2002)	Demonstrate knowledge and understanding of, and competence with, ICT.	X	X		X	X			X		
	Use effective teaching and assessment methods.							X	X		
	Be aware of health and safety, legal and ethical issues relating to the use of ICT.										X
	Research and categorize information.		X								
	Develop and model information.		X				X				
	Present and communicate information.		X								
	Understand how pupils' learning can be affected by their physical, intellectual, linguistic, social, cultural and emotional development.									X	
	Master productivity packages, e-mail and browsers.		X								
Kozma & McGhee (2003)	Use productivity tools, e-mail, and search information in the Internet.	X	X								
	Use variety of ICT-resources like multimedia.					X					
	Foster student acquisition of problem solving and collaborative skills.					X				X	
	Manage new pedagogical skills when teaching with ICT.					X			X		
	Design and create materials with ICT.						X				
	Advise/guide students.					X					
	Monitor students' progress.					X		X			
	Collaborate with peers from inside/outside the school.			X							
	Involve with scientific or higher education institutions.			X							
Cox, Webb, Abbot, Blakeley, Beauchamp, and Rhodes (2004)	Understand the relationship between a range of ICT resources and concepts, processes and skills in their subjects.					X					
	Use their subject expertise to obtain and select appropriate ICT resources which will help them meet the pupils' learning objectives.				X	X					
	Knowledge of the potential of ICT resources.							X	X		
	Confidence in using a range of ICT resources.	X	X								
	Understand that some uses of ICT will change the nature and representations of knowledge, and the way the subject is presented to and engage the pupils.				X	X					
	Expertise in organizing pupils when using ICT resources within the class.					X					
	Know how to prepare and plan lessons where ICT is used which will challenge pupils' understanding and promote reflection and thinking.					X			X	X	

Notes. Competence A1: Demonstrate ICT Basic Skills, Competence A2: Demonstrate ICT Productivity skills, Competence B: Use ICT as mindtools and for cooperation/communication, Competence C: Select, assess and evaluate ICT products, Competence D: Use a variety of instructional/pedagogical strategies and ICT- resources for learning, Competence E: Design and produce learning materials with ICT, Competence F: Evaluate teaching and learning approaches with ICT, Competence G: Teach through/with ICT to enhance learning, Competence H: Apply Student-centered approach for teaching considering learning styles supported by ICT, Competence I: Manage social ethical issues with ICT.

Appendix 1. Teachers' competences in the information society (cont.)

	Competences/Standards	A1	A2	B	C	D	E	F	G	H	I
UNESCO – ITTE (2001)	Adequate technology competence (to operate a computer and digital literacy).	X									
	ICT productivity tools.		X								
	Explode ICT characteristics to enhance the teaching and learning proces, playing a new role (to re-new curriculum, to create learning resources and environments).					X	X		X	X	
	Apply assessment and evaluation strategies and use IT in this process. Teachers should have criteria to evaluate courseware products.				X			X			
	Social, Ethical and Human Issues that aroses with the integration of ICT in Education.										X
IEPSE-ESPOL (2004)	Demonstrate basic skills in the operation of computers.	X									
	Effective use of productivity packages, e-mail, and a browser.		X								
	Manage Microworlds educational environment.					X					
	Manage Mindstorms educational environment.					X					
	Make use of data networks.		X								
	Do preventive maintenance of computational equipment.		X								
	Participate in discussion forums with colleagues for professional development.			X							
	Play the role of a facilitator in the learning process.					X					
	Foster the development of creativity and high cognitive skills through the incorporation of educational software packages.					X			X		
	Enhance the teaching-learning process with ICT.								X		
	Apply active, reflective and significant teaching-learning strategies, considering pupils' individual difference with ICT.					X				X	
	Foster work-group and collaborative based-learning.					X					
	Plan and teach with the incorporation of ICT in the classroom.					X			X		
	Design, develop, implement and evaluate educational projects mediated by ICT.						X	X			
	Apply reflective process in their teaching practice.					X					

Notes. Competence A1: Demonstrate ICT Basic Skills, Competence A2: Demonstrate ICT Productivity skills, Competence B: Use ICT as mindtools and for cooperation/communication, Competence C: Select, assess and evaluate ICT products, Competence D: Use a variety of instructional/pedagogical strategies and ICT- resources for learning, Competence E: Design and produce learning materials with ICT, Competence F: Evaluate teaching and learning approaches with ICT, Competence G: Teach through/with ICT to enhance learning, Competence H: Apply Student-centered approach for teaching considering learning styles supported by ICT, Competence I: Manage social ethical issues with ICT.

Appendix 2. Description of the IEPSE training in terms of the nine teachers's
competences in the information society

Cluster A

Teachers received training in: the use of computers; management of software
applications; maintenance of basic hardware; management of networks; the use of
productivity packages such as word processors, spreadsheets and presentation software,
and also in e-mail, and Internet browsers.

Cluster B

Teachers used on-line discussion forums to post problems, to report their progress, to
ask for additional resources, etc. The teachers progressively used ICT to develop
professional and cognitive skills in close collaboration with other teachers. This
competence is related to the use of ICT as a mindtool. Teachers used discussion forums
to plan and work out educational projects as assignments during the training. They
communicated with their colleagues and tutors through e-mail and discussion forums.
Teachers were trained in the use of two educational software packages: Lego-
Mindstorms® and Microworlds®. The results of these training experiences were
presented at the end of each school year during "open-houses". Teachers participated in
a contest for innovative projects using Lego-Mindstorms® and Microworlds® at the
end of each school year. The local community and parents could also attend these
meetings.

Cluster C

No specific competences related to cluster C -ICT products selection, evaluation and
assessment- have been addressed in the IEPSE training.

Clusters D, E and H

Clusters D, E and H. Competences in relation to these clusters were pursued in an
interrelated way. Teachers learned to design and produce educational projects and
materials at a micro level (E). When using Lego-Mindstorms® and Microworlds®, they
adopted a range of resources such us multimedia, animations, and hyperlinks. In the

workshops attended by teachers, attention was paid to the use of these tools -by the teachers- to foster the development of constructivist learning/teaching strategies (D) and allow pupils to work in line with their own learning styles (H).

Cluster H. A significant part of the IEPSE training focused on the new role of the teacher, that of a facilitator of the learning process. To support the adoption of constructivist teaching strategies, teachers were enrolled in workshops about cognitive theories and social constructivist paradigm. They learned how to promote student-centered learning and strategies for: experiential learning, active learning, reflective learning, and work-group based learning (H). The training approach helped them to apply continuously the new ideas with their own pupils alongside the training. The teacher trainers adopted a workshop style in line with this approach. The trainers adopted a coaching style during the workshops.

Clusters F and G

Because of the experiential and reflective nature of the training, teachers did not receive a separate training to evaluate teaching and learning approaches with ICT, or an isolated training to teach with ICT. There was a strong focus on designing, developing, implementing and evaluating comprehensive ICT-based educational projects, so the outcome of this approach was well-planned classroom practices that teachers applied in their own classrooms. Along with this active experimentation, classroom sessions were videotaped and presented to and discussed with other teachers. This exercise resulted in peer feedback from colleagues and coaches and ultimately in re-planning and the implementation of suggested changes.

Cluster I

No competences were dealt with in relation to cluster I about social implications of ICT-use.

Chapter 2

The impact of an ICT-teacher training programme on the teaching practices of Ecuadorian teachers. A longitudinal study[*]

Abstract

This article mirrors the results of a quasi-experimental study about the impact of an ICT teacher training programme (IEPSE) on the teaching practices of primary school teachers in Ecuador. The IEPSE-training focused on fostering the adoption of social constructivist teaching and learning principles. Results of the study researched eight teachers and their classes in an experimental and two control conditions. The study is based on video-analysis of actual teaching practices, self-reported teaching strategies and the perceptions of the pupils about the teaching of their teachers. The results indicate that the actual teaching behavior of the IEPSE-teachers has significantly changed in line with the project objectives. This is confirmed by both the video-analysis and the perceptions of the pupils. Methodological weaknesses of the study are discussed and directions for future research are suggested.

Introduction and general research question

During the last five years, an Ecuadorian university, the Escuela Superior Politécnica del Litoral, through its Information Technology Centre (ITC) has implemented a pilot project to innovate primary education in Ecuador through the use of ICT. This project is called the Innovation of Primary Education in the Santa Elena Peninsula (IEPSE) and consists of several components: (a) an in-service teacher training programme, (b) deployment of computer labs with internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and educational support for teachers trained in the programme. Teacher training has been identified as a key component to truly develop the skills needed in the citizens of the new century (Knierzinger, Røsvick, & Schmidt, 2002). An analysis of the characteristics of the IEPSE ICT teacher training programme has been reported

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[*] Partly based on a paper submitted for publication in *Teaching and Teacher Education: An International Journal of Research and Studies.*

(Chiluiza-García & Valcke, 2004). It was found that the in-service ICT teacher training programme proved to be in line with current educational and technological international trends in ICT teacher training and the current training needs of Ecuadorian primary coastal teachers. In the discussion section of this previous study, it was suggested a follow-up study to research actual teaching principles promoted in the classroom by analyzing the actual teaching activities of teachers in and outside the programme.

The central research question in the present study is: What is the long term impact of the IEPSE programme on the teaching strategies adopted by the teachers in their classroom? In view of answering this question, a quasi-experimental study has been set up. In the study we analyze the observed and self-reported teaching strategies of primary school teachers that have been involved during three years in the IEPSE-programme. Also the perceptions of the pupils about the teaching principles adopted by their teachers are considered in this study. The study analyses the differences in the teaching strategies fostered by teachers after 2 and 3 years of being involved in the IEPSE programme. Before discussing the research design and results of the study, a brief review is presented of variables and processes that affect adoption of ICT-use by teachers in their daily classroom practice. This helps to position and typify the IEPSE teacher education programme.

Variables and processes affecting the adoption of ICT-use in daily teaching practice

The potential advantages of ICT in education are widely recognized; e.g., it promotes the development of skills needed in the information society, such as thinking skills and problem solving skills; it has a positive association with students' achievements (Cox et al., 2004a; Henderson, Klemes, & Eshet, 2000; Mc Guiness, 1999; Murphy et al., 2002; Pelgrum, 2001; Schacter, 1999; Valdez et al., 2000; Waxman, Lin, & Michko, 2003). But the positive perceptions and expectations about the impact and relevance of ICT has recently been questioned due to the sharp contrast between the great investments governments all over the world have put in the deployment of ICT and the lack of research evidence that demonstrates an improvement of teaching practices and ICT-based learning (Conlon & Simpson, 2003; Cuban, 2001; Reynolds, Treharne, & Tripp, 2003). Several studies have tried to identify key variables or processes that help to explain the poor adoption of ICT in daily classroom practices. Some studies focus on contextual and external variables that help to promote effective ICT-adoption, such as

school ICT policy, good technological support in-situ, time and access to computers outside the classroom to prepare and plan ICT-based lessons (Reynolds et al., 2003); number of students in class, student access to technology time and access to equipment (Smeets & Mooij, 2001); collaboration and support from colleagues, effective leadership in schools, commitment of the school community (Granger, Morbey, Lotherington, Owston, & Wideman, 2002; Jongmans, Biemans, Sleegers, & De Jong, 1998; Ruthven, Hennessy, & Deaney, in press); motivating examples of classroom uses, availability of curricular materials (Conlon et al., 2003; Gonzales, Picket, Hupert, & Martin, 2002). But given the focus -in this article- on teacher training, we especially center in this study on internal variables that are related to the teacher as a professional.

A review of the literature results in a first set of teacher characteristics that is considered to be a clear predictor of the actual adoption of ICT in daily teaching practice: the mastery of technical ICT skills, and teacher perceptions, beliefs and conceptions. The former is related to other factors found in research such as computer experience and teaching technology-related subjects as factors that account for the use of ICT in classrooms; however, individual characteristics as technological innovativeness are also key factors for ICT inclusion in the classroom (Van Braak, 2001). However, according to Becker (2001) ICT knowledge is the strongest predictor of future ICT-use. This is also confirmed in recent overview studies of Cox et al. (2004b) and Reynolds et al. (2003).

The latter and by far the most promising set of teacher characteristics is related to teacher perceptions and beliefs about the relevance of ICT-use in instruction. Reynolds et al., (2003) refer to the teachers' faith in that ICT will really improve their teaching and the pupils' learning. Teachers' beliefs and their conceptions of learning affect their teaching practices (Bolhuis & Voeten, 2004; Kynigos & Argyris, 2004). In addition, it has been found that the beliefs are closely related to the quality of preservice experience, opportunity of reflection on the preservice experience, among others (Fang, 1996; Kroll, 2004). Smeets & Mooij (2001) indicate e.g., that teachers' educational perspectives are closely related to their actual teaching and linked to the way ICT is used in the classroom. They found that teachers with traditional approaches to instruction -unidirectional instruction- preferred skill-based software e.g., drill and practice or tutorials that were used to reinforce skills or motivate pupils; whereas teachers with constructivist views of teaching and learning favored skills-based as well as open-ended ICT-tools e.g., problem solving, multimedia applications and

telecommunications, that allow the generation of pupil-centred learning environments and the stimulation of active learning in children. This is confirmed in the extensive review of the literature and research by Cox et al. (2004b). They point out that crucial elements in the use of ICT in schools are the educational approaches fostered by the teachers. Gonzales et al. (2002) recognize the need to change beliefs or reorient teachers in their epistemologies from direct instruction to constructivist teaching methods in order to be able to incorporate ICT in a relevant way. This is in line with Baggott La Velle, McFarlane, & Brawn (2003), Law, Lee, & Chow (2002), Smeets et al., (2001), Tynjäla (1999) who also stress a *pedagogical shift* or paradigmatic change to actually prepare workforce of the future for life long learning through the inclusion of situated, collaborative and real-world learning experiences in the educational environment. In the context of this discussion, part of the debate focuses on the possibility to change teachers' beliefs. Research evidence indicates that it is difficult, but nevertheless possible (See e.g., Benjamin, Russo & Kefover, 2004; Howard, McGee, Schwartz, & Purcell, 2000). Teacher education is central in this context. The authors stress that the teacher education programme has to reflect the paradigm shift. The adoption of constructivist approaches in the ICT teacher education is important to produce the necessary epistemological changes in teachers' philosophies (Cox et al., 2004b; Dawes, 1999; Demetriadis et al., 2003; Gonzales et al., 2002; Howard, McGee, Schwartz, & Purcell, 2000; Pedersen & Liu, 2003). The approach towards ICT teacher education in the IEPSE project is in line with these findings. Before being able to discuss this programme, the constructivist approach to learning and instruction is briefly presented.

<div style="text-align:center">The constructivist approach towards learning and instruction</div>

Duffy & Cunningham (1996) present two basic principles that typify constructivist instruction: (a) learning is an active process where knowledge is constructed and not acquired, and (b) the process of instruction supports knowledge construction rather that communicating that knowledge. According to the constructivist view the learner is an active organism, who engages in the meaning making and sense seeking, rather than a passive one that responds to stimuli (Perkins, 1992). Moreover, constructivist learning is characterised by involving learners in situated and authentic activities that reflects the real world (Duffy & Jonassen, 1992). Learning is active (manipulative/observant), constructive (articulative/reflective), intentional (reflective/regulatory), authentic

(complex/contextualized/realistic), and cooperative/ collaborative/ conversational / socially negotiated (Bednar, Cunningham, Duffy, & Perry, 1992; Driscoll, 2000; Jonassen, Howland, Moore, & Marra, 2003; Schunk, 2004).

Constructivist instruction applies instructional strategies that are consistent with the constructivist approach towards knowledge and learning. For instance, the instruction is set in (simulated) real-world contexts. Teachers adopt the cognitive apprenticeship model and coach students toward expert performance in their zone of proximal development (Schunk, 2004). They invite them to construct knowledge, to consider multiple perspectives, to get ownership of learning, to reflect on their own activities/self-awareness (Driscoll, 2000). The latter implies a fundamental shift in the evaluation approach that builds on actual performance in authentic tasks. The teacher stresses self-evaluation and fosters the development of self-reflection and metacognitive skills (Bednar et al., 1992).

The IEPSE training programme

The former paragraphs put forward a clear set of requirements for designing and implementing an ICT teacher education programme. It is in this context that we describe the approach adopted by the IEPSE project. This project initiated its teacher education component in May 2002. Initially 20 rural and urban-marginal primary schools in the Peninsula of Santa Elena were involved, i.e., 40 teachers and nearly 8,000 pupils from first to sixth grade (6-11 years old). Currently, more than 43 schools are part of the IEPSE-network and more than 10,000 pupils are expected to be influenced.

Regarding the characteristics of the training, two teacher trainers and four educational/technological supports were involved at the beginning of IEPSE project. Due to time constraints of in-service teachers and also to the novelty of a great part of the content, teachers have participated in the training for 2 years in workshops (320 hours in total) that progressively increase in the level of difficulty. Teachers have attended to 8 intensive workshops of 40 hours each during these 2 years.

IEPSE aims at developing through the intensive training two types of competences in teachers: (a) technical and (b) educational competences. IEPSE trained teachers are expected to demonstrate basic ICT and productivity skills, to use ICT for cooperation/communication, to manage a variety of instructional/educational strategies and ICT- resources for learning, to design and produce learning materials with ICT, to

evaluate teaching and learning approaches with ICT, to teach through ICT to enhance learning, and to adopt a student-centered teaching style. The IEPSE project reflects an integrated training model, the development of the ICT-teaching skills is intertwined with the development of the educational competences. IEPSE staff promoted a shift from direct instruction to more constructivist instruction, otherwise as stated by Ruthven et al. (in press, Conclusion section, ¶1) we would only see "modifications to the texture of classroom teaching and learning than of any radical refashioning."

Teachers trained by IEPSE teach computing classes after regular school hours in combination with their teaching responsibilities for a specific school grade. Thus, both technological and educational follow-up activities after the training tracked and promoted the further integration of ICT in the teachers' regular classroom, and the adoption in daily teaching practice. Periodical meetings gave teachers the opportunity to present their classroom applications of ICT linked to a subject different from technology-related classes. Some meetings resulted in real-life class demonstration, while IEPSE and school colleagues, principals and IEPSE tutors attended the activity and gave feedback. During the school year, teachers were visited regularly. For more details about the IEPSE training see Chiluiza-García & Valcke (2004).

Research design

Research questions

As stated earlier, the central research question in this article is: What is the impact of the IEPSE programme on the daily teaching practices of Ecuadorian coastal teachers? In view of answering this question about the impact of the project, this quasi-experimental study tests the following hypotheses:

1. IEPSE-teachers have adopted to a higher extent social-constructivist teaching principles in their science classroom practice as compared to non IEPSE-teachers.
2. IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice will be higher as compared to non IEPSE-teacher ratings

3. IEPSE-pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles by their teachers in science classroom practice will be higher as compared to non IEPSE-pupil ratings.

4. IEPSE-teachers have adopted to a higher extent in 2003 social-constructivist teaching principles in their science classroom practice as compared to 2002.

5. IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice in 2003 will be higher as compared to 2002.

Research approach

In view of the research problem two research methods were chosen: observation of classroom teaching activities and the administration of questionnaires. The adoption of the non-participant observation assures the collection of rich process data about the actual adoption of teaching strategies in the classroom. It is to be stressed that regular classroom activities were studied and not the ICT-based teaching activities. This approach is crucial to be able to detect the impact on regular classroom activities. Science teaching activities were observed, video-recorded and analyzed with the Constructivist Teaching Inventory – CTI (Greer, 1997). Next, both pupils and teachers involved in the study, were asked to fill out the Constructivist Learning Environment Survey – CLES (Taylor, Fraser, & Fisher, 1997). The information derived from these data help to study what the teachers and the pupils in experimental and control conditions report about the adoption of constructivist teaching principles in their classes.

Research sample

A stepped procedure was followed to get a sample of eight fifth-grade teachers and their pupils to be involved in the study. As has been explained elsewhere (Chiluiza-García et al., 2004), there are 137 primary schools in the Peninsula region. At the launch of the IEPSE-project, 43 schools were randomly selected from this total number of schools (based on a code assigned to a school). These schools were invited to participate in an introductory conference. Due to resource limitations, only 20 schools could join in the IEPSE-project. Involvement or non-involvement of schools was based on commitment

for completing the training programme and whether teachers were able to follow the
training linked to the project. Six teachers were selected from the list of all fifth-grade
teachers that teach in these twenty schools; three IEPSE-teachers that personally have
been enrolled in the IEPSE-training (experimental group), and three teachers of schools
enrolled in the IEPSE-programme but who did not participate personally in the training
(control group A). Next, three fifth-grade teachers were selected ad random from the 23
schools that were – yet - not included in the IEPSE-project, and consequently did not
receive an IEPSE training (control group B). But only 2 teachers answered positively to
the request to participate in control group B. A further selection and invitation did not
yield positive results; thus control group B consisted of only 2 teachers.

The eight teachers selected in the present study work in rural schools of the
Peninsula region; they are 45 years-old in average; they have a diploma in primary
education; did not follow post-graduate studies; they did not have previous experience
with ICT; and only two of them are female. These teachers' characteristics are
comparable to the average coastal region teacher in the Santa Elena Peninsula (Chiluiza-
García et al., 2004).

It has to be stressed that the sampling approach focused on schools and teachers.
We involved the pupils of the classes that were the responsibility of the selected
teachers. The total number of pupils in the 8 classrooms was 249. The data of 204
pupils could be used in the context of the present study. Due to the longitudinal nature
of the study, only 204 pupils participated in all the stages of the study; some moved to
other villages/schools, were ill, or missed a session, etc. In addition, it is important to
state that a long strike occurred during the period of data gathering of the study in 2003.
This also has affected the number of participation/attendance of pupils to the different
phases of the study. Of the research group, 43% are female and 57% male; all of them
are between 11 and 12 years old (year 2003). The number of pupils was different in the
conditions: experimental group=86, control A=89, and control B=29.

Research variables and research instruments

Based on the observation technique, data was gathered about the actual observed
adoption of teaching strategies. Based on the questionnaire, data was gathered about the
self-reported adoption of constructivist teaching strategies and from the pupils about
their report of specific teaching strategies adopted by their teachers.

Teachers' self reports and pupils' perceptions were gathered using the CLES, developed by Taylor, Fraser & Fisher (1997). A pupil version and a teacher version available of this instrument exist. It evaluates the perceived constructivist environment -as reflected in specific instructional techniques- fostered by teachers in science classes. The 25 items represent five subscales: personal relevance (PR), uncertainty (UN), shared control (SC), critical voice (CV), and student negotiation (SN). PR refers to the perceived relevance of what pupils learn at school related out of school experiences and how teachers build on these experiences of pupils. UN corresponds to the extent to which opportunities are provided for pupils to experience knowledge as arising from personal experience and values, and as culturally and socially determined. SC reflects the extent to which pupils share control of their learning environment with the teacher. CV represents the extent to which students feel that it is rightful and positive to question their teacher's plans and methods, and to express their concerns to others about learning. SN assesses the extent to which pupils explain and justify their ideas to others, appreciate each others ideas and reflect on their viability. Teachers and pupils react to each item on a Likert scale (1 = never to 5 = always). The reported Alpha-reliability coefficient for this tool is between .90 and .85 (Lee & Fraser, 2001; Puacharearn & Fisher, 2004).

Data about the variable "adoption of constructivist teaching strategies" was gathered through the observation and analysis of videotaped classroom interaction. The CTI (Greer, 1997) was used for the analysis. The CTI helps to determine the level of adoption of constructivist teaching principles. It is based on a 44-item inventory, divided into 4 sub-scales: Community of learners (CL), teaching strategies (TS), learning activities (LA) and curriculum and assessment (CA). CL represents the social aspect of constructivist knowing and learning; TS corresponds to the decisions a teacher has to make about planning and implementing instruction; LA corresponds to the characteristics of the activities students are requested to perform and CA represents how content and process skills are organized and selected, it also represents the means and reasons for assessment and the way the assessment results are used. The CTI asks observers to rate teaching behavior. The rating reflects to what extent a typical strategy has been observed (varying from 0 and 6). As such, the highest total score is 264. Reported Alpha-reliability is .99 (Greer, 1997).

Both instruments were translated from their original version into Spanish, using translation and back-translation method as described by Behling & Law (2000). The

Spanish versions were pilot tested using a small sample of teachers and pupils to ensure their clarity and legibility. These teachers and pupils did not participate in the further study.

Procedure

This study started in 2002, two years after the beginning of the training process. Two to three science classes were recorded, for each of the 8 fifth-grade teachers. A first set of sessions was videotaped at the end of 2002. A second set was videotaped at the end of 2003. At the end of each recording session in a specific class, the teacher and the pupils were invited to fill out the CLES questionnaire.

The video recordings were analyzed by a group of three independent researchers. They received a training to work with the CTI-instrument in order to reach high interrater reliability. All recordings were observed and analyzed simultaneously by the researchers. To assess the quality of the coding Cronbach-alpha was calculated. A value of 0.7 was put forward as a criterion for interrater reliability. At the end of each coding session interrater reliability was calculated and resulted in high Cronbach-alpha coefficients (.83 to .86 for year 2002; .86 to .94 for year 2003). To control for systematic differences in coding, the coding session was extended with a discussion about the differences in coding. This approach has been found to be useful to assure consistency (Stemler, 2004). The approach followed could result in some minor changes in coding by a coder. After this discussion phase interrater reliability was recalculated (.83 to .89 for year 2002; .90 to .99 for year 2003). To check whether it was not always the same researcher changing the coding category, *Cronbach α* was also calculated for each individual researcher resulting in an α coefficient between .70 and .92 in both years.

Statistical analysis

Statistical analysis for this study is initially based on descriptive statistics. The non-parametric tests Kruskal-Wallis and Wilcoxon test were used to compare the CTI-scores and CLES self-ratings of teachers in the different conditions. Univariate ANOVA and MANOVA have been used to analyze the perceptions of the pupils. In addition, a non-parametric repeated measure test was used to compare teacher's performance in this longitudinal study.

Results

Table 1 summarizes mean CTI-scores for each condition in 2002 and 2003. Mean CTI scores are higher in the experimental group than in both control conditions.

Table 1. Means for Total CTI Score and CTI dimensions per group per year (*N* = 18 video-taped lessons in 2002, *N* = 16 video-taped lessons in 2003)

	Group	Mean CTI	Mean CL	Mean TS	Mean LA	Mean CE
Year 2002	Experimental	63.33	18.17	14.67	15.83	14.67
	Control A	33.17	9.67	7.17	8.17	8.17
	Control B	39.50	9.50	10.5	9.48	10.30
	Whole Group	46.06	12.81	10.81	11.37	11.14
Year 2003	Experimental	118.17	34.83	28.17	32.17	23.00
	Control A	46.83	13.67	11.17	11.17	10.83
	Control B	33.00	7.50	10.75	6.50	8.25
	Whole Group	70.13	20.06	17.44	17.88	14.75

Figure 1 gives a graphical representation of this information, but gives in addition the relative position of the CTI-scores of the individual teachers in the experimental (1-3) and control conditions (control A=4-6 and control B=7-8).
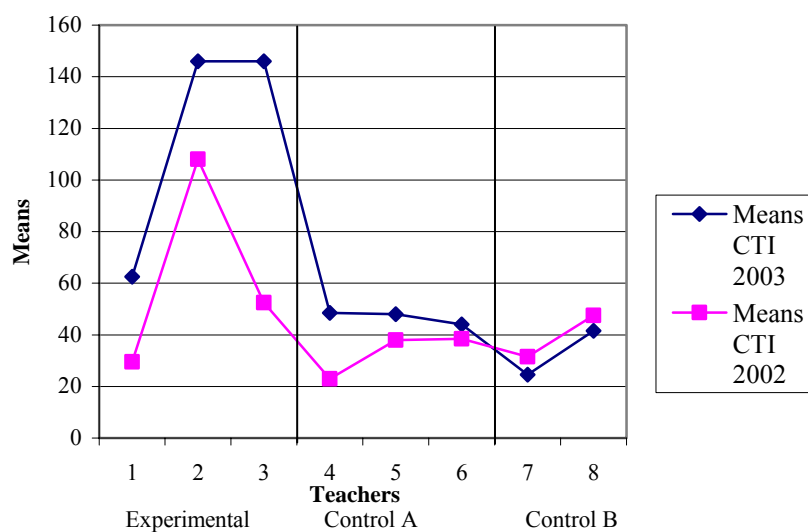
Figure 1. Means' profiles for CTI-General scores in year 2002 and year 2003.

As to the CLES, the mean score in 2002 is *M*=7.69 and in 2003 is *M*=8.08. Only for descriptive purposes, two levels of self-reported adoption and observed adoption of constructivist teaching were calculated. Figure 2 depicts the self-reported CLES levels in a graphical way and at the same time contrasts these levels with the CTI-levels that represent the actually observed level of adoption of constructivist teaching strategies. It is interesting to observe the (in)consistencies in these data when comparing experimental and control groups.
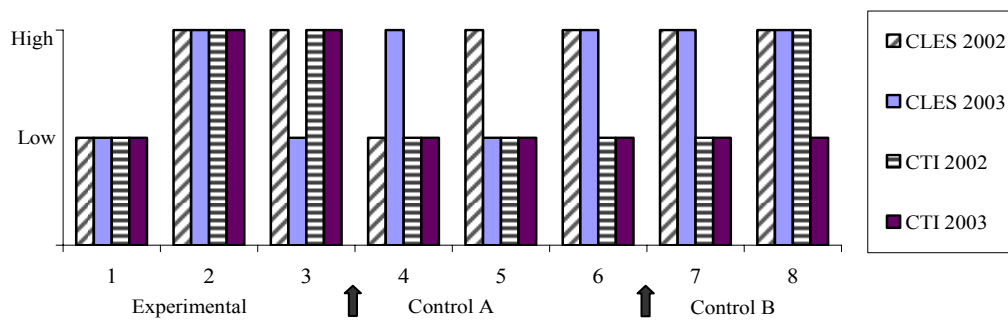

Figure 2. Self-reported and observed levels of adoption of constructivist teaching strategies of teachers in 2002 and 2003

Table 2 summarizes the results obtained from applying CLES-version for pupils in year 2003. Overall reliability of the test is α =.73. Further analysis of the subscales reveals that some of these subscales do not reflect high reliability scores. Therefore, only the subscales "shared control" and "student negotiation" with acceptable α-values and the total score of CLES will be used when testing hypothesis 3. The CLES (pupil version) was also administered in 2002, but the data were incomplete and unreliable and therefore not used in this study.

Of interest is an analysis of the correlation between (a) the CLES self-ratings of teachers, (b) the CLES average ratings reported by the pupils and (c) the actual adoption of constructivist teaching practices as observed with the CTI. There are no significant correlations between the CLES-ratings obtained from teachers and pupils (*r*=-.37, *p*=.368 2- tailed) or between the CTI-scores and the CLES-ratings of the teachers (*r*=-.16, *p*= .714 2-tailed). However, there is a significant positive correlation between CTI-scores and the CLES average ratings of the pupils (*r*=.71, *p*=.048, 2-tailed).

Table 2. Descriptive statistics of the CLES ratings and CLES dimensions, pupil version for year 2003 (*N*=204)

Groups	Experimental (*n*=86)		Control Group A (*n*=89)		Control Group B (*n*=29)	
Scales	*M*	*S.D.*	*M*	*S.D.*	*M*	*S.D.*
Total Score	93.40	8.80	86.35	9.64	83.17	8.29
Personal relevance	20.42	1.97	20.40	2.55	18.17	3.05
Uncertainty	19.93	2.31	20.83	2.37	17.00	2.99
Critical voice	17.65	3.24	14.45	3.65	16.41	2.47
Shared control	16.30	3.79	13.33	4.02	14.52	2.53
Student negotiation	19.12	2.35	17.33	3.42	17.07	2.89

Hypothesis 1: IEPSE-teachers have adopted to a higher extent social-constructivist teaching principles in their science classroom practice as compared to non IEPSE-teachers.

The Kruskal-Wallis test was used to test this hypothesis for the data (mean CTI-scores) of 2002 and 2003. Table 3 summarizes the results of the test. In 2002 no significant differences can be observed between the teachers in the three conditions. In 2003, significant differences are found for the total CTI-score and at subscales level CL, LA, CA. Further tests were run to identify the condition(s) that significant differ from one another. Because of the small sample size, it was not possible to test the differences in experimental group and control group B. Wilcoxon test was run and yielded significant differences between experimental and control group A (*p* = .05, 1-tailed) for the total CTI–score (*z* = -1.993), and the subscales LC (*z* = -1.964), LA (*z* = -1.964) and CA (*z* = -1.993). Based on these results, the null hypothesis is rejected. IEPSE-teachers have adopted to a higher extent social-constructivist teaching principles in their science classroom practice.

Table 3. Results of the analyses in relation to Hypothesis 1 and 2 (*N*= 8)

Instrument	Dimension	Year 2002			Year 2003		
		df	χ^2	*p*	*df*	χ^2	*p*
CTI	Community of learners	2	3.85	.186	2	6.25	. 011 *
	Teaching strategies	2	1.44	.557	2	2.73	.314
	Learning activities	2	1.01	.657	2	6.25	.011*
	Curriculum and assessment	2	1.01	.689	2	6.01	.014 *
	Total Score	2	1.36	.564	2	6.33	.011 *
CLES	Relevance	2	.23	.946	2	1.83	.432
	Uncertainty	2	.16	.979	2	1.92	.443
	Critical Voice	2	1.46	.582	2	0.57	.764
	Shared Knowledge	2	2.05	.400	2	3.18	.261
	Negotiation	2	3.22	.211	2	0.50	.786
	Total Score	2	.83	.732	2	3.14	.243

*p< .05

Hypothesis 2: IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice will be higher as compared to non IEPSE-teacher ratings.

In Table 3, the reader can also find the results of the Kruskal-Wallis test for this hypothesis. No significance differences between the three conditions can be observed. The null hypothesis cannot be rejected. IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice are not higher as compared to non IEPSE teacher ratings.

Hypothesis 3: IEPSE-pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles by their teachers in science classroom practice will be higher as compared to non IEPSE-pupil ratings.

Univariate ANOVA was used to test differences in mean CLES-ratings of pupils in the three conditions. A significant main effect is observed. Pupils with IEPSE-teachers report significantly higher average ratings of adoption of social constructivist teaching

principles by their teachers F (2,201) = 19,75 (p<0.001) and partial η^2 = .16 (.01, .06, .14 indicate small, medium, or large effect sizes; Cohen, 1988).

The analysis was continued by focusing on the CLES-subscales. MANOVA was run, with the two subscales of the CLES (shared control and student negotiation) as the dependent variables and conditions as the independent variable. Pillai's trace statistic was used to analyze the differences among means. Pillai's statistic value (.17) was significant F(4, 402) = 9.32 p< .0001, partial η^2 = .09. Univariate analysis (ANOVA) for each dependent variable reflects significant differences between conditions for each dependent variable: Shared control, F (2,201) = 13.76, p<.0001, partial η^2 = .12; Student negotiation, F(2,201) = 9.92, p<.0001, partial η^2 = .09. *Post hoc* analysis was performed with the level of significance set to p = .01. Variances were not homogeneous (Levenes' test). Table 4 summarizes the values of the Tamhane multiple comparisons.

In general it can be concluded that there are clear significant differences between the pupils in control group B and those in control group A, and the experimental group.

The null hypothesis can be rejected. Pupils taught by IEPSE-teachers or with teachers of schools in the IEPSE-project report higher average ratings about their perceptions of adoption of social-constructivist teaching principles by their teachers.

Table 4. Post hoc analysis of differences between the experimental and control group A and B two subscales of the CLES

Dependent variable	Differences among means in Tamhane multiple comparisons
Shared control	Experimental –Control A (2.96) **
	Experimental – Control B (1.77) *
	Control B – Control A (1.19)
Student negotiation	Experimental –Control A (1.78)**
	Experimental – Control B (2.05)**
	Control A – Control B (.2681)

Note. Mean differences among each group appear in parentheses.

*p<.017, **p<.005

Hypothesis 4: IEPSE-teachers have adopted to a higher extent in 2003 social-constructivist teaching principles in their science classroom practice as compared to 2002.

To test this hypothesis, we used the non-parametric Wilcoxon signed ranks test for paired data (mean CTI-scores). Because of the small sample size, the analysis remains limited and between groups analysis is not possible. Nevertheless, the results reveal that IEPSE-teachers have adopted to a significantly higher extent social constructivist teaching strategies There are significant differences for each CTI-subscale (exact $p < .05$, 1-tailed), with the exception of the scales, Learning activities ($p = .055$) and Curriculum and evaluation ($p = .059$), which only reached meaningful levels of significance. Nevertheless, the null hypothesis can be rejected. In 2003, IEPSE-teachers have adopted to a higher extent social-constructivist teaching principles in their science classroom practice.

Hypothesis 5: IEPSE-teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice in 2003 will be higher as compared to 2002

None of the analyses result in significant differences. The final CLES self-ratings are not significantly different from the -already high- CLES self-ratings in 2002. As a result, the null hypothesis cannot be rejected.

Discussion

The aim of this study was to answer the following question: What has been the long term impact of the IEPSE programme on the teaching strategies adopted by the teachers in their daily classroom teaching? In view of answering this main question five different hypotheses were tested. In the next paragraphs, the discussion will be structured along these hypotheses.

In 2002, the authors of the present study could not observe significant differences in the average adoption of social constructivist teaching principles between teachers in experimental and control conditions. These results were not unexpected. There is clear evidence that the application of newly learned teaching strategies is a

slow and complex process (Lowther, Ross, & Morrison, 2003; Richardson & Placier, 2001). Richardson et al. (2001) state that change in teaching requires a *normative-reeducative* approach which requires deep changes in content and pedagogical knowledge. Accordingly, this modification of teaching strategies depends on the initial adoption and change of beliefs and epistemologies about teaching and learning (Becker, 2001; Cox et al., 2004b; Howard et al., 2000; Kynigos et al., 2004).

In 2003, analysis of the impact of the IEPSE-project was researched again, one year later. The researchers expected that a longer period of time would have given teachers sufficient time to reflect on their own teaching behavior, to consider the feedback received from different sources and to gradually assimilate and accommodate what they have learned into their own set of teaching strategies (Berliner, 2001; Gonzales et al., 2002; Kroll, 2004). This extra year gave the teachers additional time to understand and untie the complexity of a pedagogical model that is generally qualified as rather complex and sophisticated (Conlon et al., 2003; Spector, 2001; Tatto, 1999). Changes in teaching practices that promote constructivism in the classroom have been reported to require more than a year to become partially successful (Ross, Rolheiser, & Hogaboam-Gray, 1998). The results of the present study are in line with the expectations. IEPSE-teachers obtain significantly higher CTI-scores when observing and analyzing their actual teaching behavior. Also at the level of the subscales the difference is significant, with the exception of the "teaching strategies" scale. Analysis of the differences between control group A and B could not be executed due to the sample size limitations. However, the means obtained by the control group B were the lowest of all the conditions in the present study.

Despite these positive results, it is important to remark that there is a pattern, already observed in 2002, that remains important in 2003. In general, teachers obtained low overall CTI-scores. The maximum score obtained by two teachers in this study is only 146 (maximum is 264).

Analysis of the CTI-scores of the teachers indicates that the average adoption based on self-report are higher than the actual adoption as observed in classroom practice. Analysis of the results of a parallel administration of the CLES shows that 80% of the teachers in control conditions report higher ratings about their own adoption of constructivist teaching. It is striking that the teachers in the experimental condition reflect a more realistic estimation of their own adoption of social-constructivist teaching. We think that this is mainly related to the fact that some meaning and sense

making has occurred during these years. This finding forces us to be careful when building research on self perceptions of teachers. This is especially true in the studies that are related to ICT-use in teaching and learning. Most of these studies rely heavily on self-assessment and self-reporting by teachers (Smeets et al., 2001; Lawrenz, Huffman, & Robey, 2003). Interestingly, a similar project in the Latin-American context has encountered comparable barriers. Teachers seem to be quick in understanding and adopting the discourse related to new educational principles and an innovative programme/project, but they fail to implement these principles in the classroom (Tatto, 1999).

Pupils, whose teachers participated in the IEPSE programme, report higher average ratings about their perception of adoption of constructivist teaching principles by their teachers than the pupils of non-IEPSE teachers. The "shared control" and "student negotiation" subscale were most helpful to differentiate between these teachers. A weakness of this study is that the perception of the pupils cannot be compared to other measures of the same construct, e.g., structured interviews or a forum discussion (Lee et al., 2001). On the other hand, the high correlations between the CTI-scores and the CLES average ratings of the pupils, help us to underscore the reliability and validity of the pupil perceptions as measured with the CLES and the importance on pupils' perceptions (Denzin, 1997; Puacharearn et al., 2004).

Our results differ from results of other studies where pupil perceptions had been linked to learning outcomes of these pupils (Lawrenz, Huffman, & Robey, 2003). But these authors also refer to several studies that reflect comparable non-significant correlation between pupil perceptions and self-report scores of teachers and significant positive correlation with scores based on observations of actual teaching behavior.

When we analyze the gains in CTI-scores of the teachers between 2002 and 2003, it is already obvious from the descriptive data (see figure 1) that teachers in the experimental condition significantly outperform their colleagues in both control conditions. The teachers in control condition A also reflect a positive but very small gain in CTI-scores. The teachers in control condition B obtain lower scores in 2003 as compared to 2002. The findings help us to accept the hypothesis about the positive differential impact of the IEPSE-training. But it is necessary to stress that part of the results can have been influenced by a long strike of teachers in Ecuador during the school year 2003. No data have been gathered to account for this uncontrolled variable in this quasi-experimental setting.

A strong element of the study is that it did not only focus on outcome measures or perceptions at pretest and posttest level, but that the actual teaching process has been studied. Analysis of the video recordings of classroom teaching proved to be a valuable way of studying the adoption of innovative teaching strategies. In addition, it is important to remark that the experimental treatment targeted some of the educational needs -gathered in a previous study about teachers in the Peninsula region- and it also considered the context in which it was developed (Chiluiza-García et al., 2004). According to Galanouli, Murphy & Gardner (2004) the consideration of the context and actual educational needs of the participants is precisely a key factor for successful outcomes in ICT-training initiatives. In addition, we also consider that the follow-up activities in which teachers and the tutor team were involved helped in the adoption of the innovative teaching strategies promoted by the IEPSE team. The interaction with a mentor/scaffold turns of central importance when implementing innovations as well as coaching and follow-up over time (Bitan-Friedlander, Dreyfus, & Milgrom, 2004; Bradshaw, 2002). The long term nature of the study was also helpful to detect significant changes. Despite the rather positive results of the study, a critical analysis of the research design adopted is needed. A first issue is related to the quasi-experimental nature of the study. It has to be stressed that the sampling approach focused on schools and teachers that were linked/not linked to the IEPSE programme and attended/not attended to the training. This implies that the researchers were not able to carry out a selection based on stratification variables that reflect teacher characteristics. Moreover, we involved the pupils of the classes that were the responsibility of the selected teachers; thus selection based on stratification variables reflecting pupils' characteristics was not feasible. However, at descriptive level, the schools in the study are all public and rural schools and not advantaged in terms of teacher number, infrastructure, etc.; furthermore, teachers in these schools show similar characteristics to the ones observed in teachers in the Guayas Province in Ecuador, which is the province the Peninsula region belongs to (Mera & Zurita, 2002). Future research should pay closer attention to the random selection of pupils in the research samples. As a result, care has to be taken when trying to generalize the research findings to other teachers, schools or pupils in Ecuador.

From a methodological point of view, the number of classes and teachers is small in this research. This has affected the statistical analyses and obliged the researchers, in a number of situations to opt for non-parametric statistical tests. This

also made it not always possible to apply multivariate analysis techniques. Future research should try to involve a larger group of teachers, classes and schools. In the current study, the researchers were also limited because of practical and time constraints. The analysis of the video recordings of 2 times 8 classes per year caused a heavy work load and was very time consuming. The adoption of semi-automated coding and analysis techniques will be needed when up-scaling future research.

The number of variables and processes measured and controlled for in this study was large. But given the quasi-experimental nature of the study, this number is still limited to be able to control for all variables that might affect teacher and pupil behavior.

As stated earlier, also variables external to the teacher are known to have a large impact on ICT-adoption of teachers. Critical issues not considered in this study are e.g. the school policy, school leadership, school culture, participation of parents, ICT-skills of the pupils, teachers' conceptions of learning, etc.

In this article, little has been said about the impact of the IEPSE-project or the changes in teaching behavior on the actual learning processes and/or learning outcomes of the pupils. This is a different research question that will be dealt with in a separate research report. In the latter research reports both learning outcomes (mathematics scores) and process outcomes (levels of cognitive processing) will be studied of pupils in the three conditions.

Conclusions

What is the long term impact of the IEPSE programme on the teaching strategies adopted by the teachers in their classroom? Pulling together the results of this study, it can be concluded that there was a significant positive impact of the IEPSE-teacher training on instructional practices in the Ecuadorian primary schools involved in this study. The IEPSE training programme has changed the way participating teachers teach and think about their own teaching. But it was also stated that these changes are still small. The CTI-scores observed in the classroom practice of the experimental teachers are still modest.

The IEPSE training model might be applicable to other rural areas in the Guayas Province -the province to which the Santa Elena Peninsula belongs-, where similar

settings are found; however, the researchers do not suggest a blind application of the model. More research is needed to be able to generalize the results of this study and to determine whether the teacher training is transferable to other schools and/or regions.

Next to the actual adoption of new teaching strategies by IEPSE-teachers, IEPSE pupils perceive higher average adoption of social-constructivist teaching principles by their teachers in their classrooms. But again, more research is needed to be able to generalize the findings. Future research should pay closer attention to the nature of pupils, teachers and schools that participate in the study. Next, variables external to the teacher should be considered and measured to account for differences between conditions and determining the adoption of new teaching strategies.

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Chapter 3

The impact of Logo as a mindtool on cognitive processing levels of 5th graders[*]

Abstract

Eight classes of 5th graders were involved in a quasi-experimental research to study the impact over time of an ICT-based project on levels of cognitive processing. The impact was studied on a non-ICT collaborative task. The study was set-up in the context of a large scale innovation Ecuadorian project. Group-work activities of pupils in experimental and control conditions were videotaped and analyzed after two and three school years in the project. The analysis scheme of Gunawardena, Lowe & Anderson (1997) was used to code the pupil activities according to levels of cognitive processing. The results indicate that the pupils in the experimental group reached significantly higher levels of cognitive processing when solving a group problem. There was a strong interaction between pupils' perceptions of high constructivist instructional principles and their levels of cognitive processing. Additionally, field-independent pupils significantly demonstrate high levels of cognitive processing.

Introduction and general research problem

The present study researches the impact of learning in an innovative computer-based learning environment on the cognitive learning processes of pupils. The research is linked to the evaluation of the innovation of education in the Santa Elena Peninsula project (IEPSE) in Ecuador. This project focuses on teachers to promote the adoption of social-constructivist instructional principles, such as active learning, self-reflection, and collaborative learning in their teaching activities. In the IEPSE initiative, teachers used Lego Mindstorms® and Logo Microworlds® with 5th grade pupils of Ecuadorian coastal rural-public schools for a period of three years. The present study reports about the impact of the use of these *mindtools* on the pupil performance. Other research reports have focused on the long-term changes in teaching behavior of teachers in the project Chiluiza-García & Valcke (2004a). The present report analyzes the impact of the project on the cognitive processing of the pupils and the extent to which the impact is influenced by the adoption level of social constructivist instructional principles by their

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teachers. This brings us to the central research problem for this research article. What is the impact over time of the IEPSE project - and the subsequent changes in the learning environment - on the actual cognitive processing of the pupils?

In this article, we first present a description of the IEPSE-project. Next we discuss the conceptual base and review the available theoretical and empirical base in relation to Logo-use in school, before presenting a discussion of the key research variables in the study. The theoretical discussion is the base for developing the research design. After presentation and discussion of the results, directions for future research are given.

The IEPSE project

During the last five years, an Ecuadorian university, the Escuela Superior Politécnica del Litoral (ESPOL), through its Information Technology Centre (ITC) has implemented a large-scale project to innovate primary education in Ecuador. A central element in the project was the use of information and communication technologies (ICT). The IEPSE project consists of several components: (a) an in-service teacher training programme, (b) the deployment of computer labs with Internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and pedagogical support for teachers trained in the programme. 20 primary schools, 40 teachers and nearly 8,000 pupils from first to sixth grade (6-11 years old) were initially involved in the project. Currently, more than 43 schools are part of the IEPSE-network and more than 10,000 pupils are expected to be influenced.

Characteristics of the IEPSE teacher training

IEPSE teachers were trained to adopt social-constructivist instructional principles in their classrooms while integrating ICT tools into their teaching. Constructivist learning is characterized by involving learners in situated and authentic activities that mirror the real world (Duffy & Jonassen, 1992). Learning is active (manipulative, observant), constructive (articulative, reflective), intentional (reflective, regulatory), authentic (complex, contextualized, realistic), and cooperative, collaborative, conversational and socially negotiated (Bednar, Cunningham, Duffy, & Perry, 1992; Driscoll, 2000; Jonassen, Howland, Moore, & Marra, 2003; Schunk, 2004). Several methods of instruction that foster conditions for constructivist learning have been suggested e.g.,

the use of microworlds, problem-based learning, collaborative learning, hypermedia, open-ended learning environments, role plays, etc. (Driscoll, 2000).

The IEPSE training helped to experience hands-on the above principles about learning and instruction. The teachers were also trained to master the didactical strategies that promote constructivist learning. The IEPSE teachers learned to design complex, relevant and contextual tasks that are to be tackled in a collaborative way by the pupils. These tasks involve the use of mindtools, such as Logo-Microworlds® and Lego Mindstorms®. These tools are considered to be *mindtools*, since they are in line with the definition of Jonassen: (a) the ICT-application can be used to represent knowledge; (b) the experience is generalizable to content in different subjects (in this case mathematics, natural sciences, geography, etc.); (c) it engages learner in critical thinking about the subject; (d) it develops skills transferable to other subjects; (e) it significantly restructures or amplifies thinking and (f) it is learnable in 2 hours or less (Jonassen, 1996; Jonassen et al., 2003).

As is the case in most constructivist teaching approaches, most instructional strategies are based on collaborative learning and problem-based learning. The didactical strategies - developed in the IEPSE teachers - helped pupils to engage in social negotiation and to explore multiple ways to look at and to solve problems. In the next sections we will centre on the Logo learning environment.

The ICT-based learning environment: Logo

The research literature is clear about the potential of ICT as a tool and catalyst to foster learning. ICT is projected and expected to help to create, collect, store, and use newly built knowledge and information. Review studies and individual research reports suggest that the use of ICT promotes the development of skills needed in the information society, such as thinking skills and problem solving skills. ICT is also positively associated with student achievement in a variety of knowledge domains (Cox et al., 2004; Mc Guiness, 1999; Murphy et al., 2002; Schacter, 1999; Valdez et al., 2000; Waxman, Lin, & Michko, 2003).

The Logo-programming language was developed as tool to foster the collaborative construction of knowledge (Papert, 1980). Murphy et al. (2002) found in their review about promising educational software, including Logo, positive results especially in reading and mathematics. Cox et al. (2004) - in a very recent update of the ICT research literature - are in agreement with these results and point out that especially

Logo and subject-based mathematics software have clearly been linked to the attainment of higher test performance scores. The potential of Logo has been extensively studied and researched in the 80's and the early 90's. Most of this research focused on measuring learning outcomes such as mathematics and geometry, the demonstration of metacognitive skills and cognitive skills, next to a strong focus on the acquisition of Logo and programming skills (Chang, 1989; Valcke, 1991). The following was identified as valuable cognitive outcomes of Logo-use: higher levels of mathematical thinking (especially geometric thinking), a more generalized and abstract view of mathematical objects, a deeper conceptualization of fundamental concepts in geometry, and the development problem-solving skills (Cathcart, 1990; Chang, 1989; Clements, 1990; Clements & Nastasi, 1992; Enkenberg, 1990; Hoyles & Noss, 1990; Many, Lockard, Abrams, & Friker, 1991; Nastasi & Clements, 1992; Nastasi & Clements, 1994; Swan, 1991; Verschaffel, De Corte, & Schrooten, 1990).

But despite the moderate positive claims about the cognitive effects of Logo, there are also the findings that learning gains are not easily transferred to other knowledge domains or contexts (Dicheva, 1996). It was also argued that the benefits of Logo and the transfer of skills acquired in Logo-based learning environments were only to be expected after the pupils worked and learned with the environment for at least a year (Clements & Meredith, 1992). The actual time spent in practicing high-level thinking skills and the frequency of this practice mediated by Logo has been found crucial to further develop and transfer the skills (Morrison, Cowan, McBride, & McBride, 1999). This will be considered in the study, discussed in this article. De Corte (1993) underscored, as a result of his review of the research, that successful Logo-studies incorporated the following aspects: (a) a good balance of discovery learning with good systematic mediation and instruction; (b) direct instruction in problem-solving skills within the Logo context; (c) a focus on specific skills to be developed (and a focus on measurement of these skills as a result of the Logo-experience) and (d) the adoption of cognitive apprenticeship teaching approaches.

The original Logo-studies have been criticized due to a number of methodological shortcomings. Too many studies were set up in artificial laboratory contexts (Verschaffel et al., 1990). Next, the findings of studies were very inconsistent and not replicable, in part due to weaknesses in the research reports, e.g., lack of clarity, lack of conceptual precision, incomplete reports, too small sample sizes, the presentation of anecdotal evidence, and a high teacher/student ratio (Valcke, 1991;

Wyatt, 1988). These issues limited the generalization of the findings. There was a clear need for a re-orientation in Logo research. Authors called for research of learning environments in more authentic school settings (Suomala, 1999). But the number of Logo-research suddenly decreased and the research virtually stopped at the beginning of the 90's. This is probably related to the too high implications of a projected integrated Logo-use in schools. For instance, the computer/pupil ratio was at that time far too inadequate. Other limitations were related to the implications of integrated Logo-use for curriculum development, exigencies for teacher training, the implications at the level of current teaching practices and rigid characteristics of the school system (Valcke, 1990a). Logo-use entails the revision and expansion of traditional activities to incorporate objectives about higher-level thinking processes (Clements et al., 1992; Hoyles et al., 1990). Another apparent reason for the decrease in Logo related research is the advent of the Internet and the possibilities it opened for a reorientation in technology related educational research.

There is currently a revival in Logo-research. Especially the perspective introduced by the concept *mindtools* has reanimated the use of microworlds and Logo-based environments. Newer versions of Logo-based learning environments have come available, and the software and technology has become more readily available in schools. We argue that it is therefore the right moment to research again the potential of Logo-based environment, but now taking into account methodological critiques on Logo and educational technology evaluation studies in general: (a) a focus on the over time impact, (b) studies in naturalistic settings, (c) measurement of the impact on near-transfer tasks, (d) and control of instructional variables (see e.g., Haertel & Means, 2000 and Rumberger, 2000). A key element in this context is a shift in focus from outcomes measurement to process analysis of the outcomes of learning with Logo.

The research variables in the study: cognitive processing, individual characteristics and the level of adoption of constructivist instructional / teaching principles

Logo, cognitive processing and knowledge co-construction

The cognitive processing of the pupils is the main dependent variable in the present study. The Logo-based activities of the pupils are expected to influence the cognitive processes that result in knowledge construction. The information processing theory of learning is helpful to explain this course of action. Mayer (1996) stressed that at the

individual level the information processing activity takes place through active engagement in selection, organization and integration processes that result in the construction and storage of mental models or schemas. The Logo-based learning environment is in this context a tool to help learners to interpret and organize their personal knowledge (Jonassen & Marra, 1994; Jonassen, Carr, & Yueh, 1998). The knowledge objects that can be programmed with Mindstorms® and Logo Microworlds® are easily linked to prior knowledge and function as *objects-to-think-with*. Due to the graphical and appealing nature of the objects, learners are facilitated in the selection of information, the organization of this information and the integration with existing and new schemas. The graphical nature of the learning objects is expected to reduce the *extrinsic* cognitive load of the knowledge elements. The concept of cognitive load has been discussed intensively by Sweller (1988, 1989, 1994) in his "cognitive load theory" (CLT). Working memory and its limitations are central in this theory. Information must be processed in this working memory before schemas can be organized and constructed and be integrated with pre-existing schemas in long-term memory. But, when the new information to be learned or its representation is too complex (e.g., too abstract), the capacity of the working memory will be exceeded, and schema construction or organization will be hindered. A major assumption of the CLT is that instruction should be structured to decrease extraneous working memory load. A number of techniques have proven to be successful in this context (see Sweller & Chandler, 1994 and Sweller, Van Merrienboer & Paas, 1998 for an overview). A key technique is to carefully prepare the concrete representations of the new knowledge elements. The Logo-learning environment is helpful to *envelop* complex knowledge concepts in objects that can easily be manipulated and controlled by learner. This new knowledge can be selected and processed more easily in working memory and more readily linked to already existing schemas in long term memory. Since Logo is expected to facilitate acquisition of the knowledge elements, a central assumption is that the learners will be able to spend more mental effort to the actual process of knowledge construction while solving complex problems. They will be able to monitor to a better extent this process. This will again result in the occurrence of more advanced knowledge processing activities.

In the literature, models can be found that present at the one hand a theoretical base - comparable to the information processing model outlined above - to describe and explain the cognitive processing impact of learning with Logo and at the other hand also

present an operationalization that is useful to analyze in a systematic way the Logo-learning activities. Alternative approaches can be found in the literature that e.g. builds on the work of Sternberg (Clements & Nastasi, 1999; Nastasi et al., 1994; Suomala & Alajaaski, 2002). These authors analyzed the Logo-activities by distinguishing between planning, monitoring and decision making during problem solving and task execution. Many Logo-researchers (e.g. Valcke, 1990a and Verschaffel, De Corte & Schrooten, 1990) tried to develop problem-solving and cognitive processing in structuring the Logo programming process as a problem solving cycle, based on Polya's model: understand the problem, devise a plan, carry out the plan, and look back and evaluate (Polya, 1957, 1973).

In their review of the research literature about the impact of Logo programming on thinking skills and problem solving, Clements & Meredith (1992) report that the research evidence to ground this assumption is less clear. But in general they report that one of the more consistent research findings is that learners develop higher cognitive monitoring skills due to Logo experiences (see e.g., Clements & Gullo, 1984; Lehrer & Randle, 1987 and Miller & Emihovich, 1986). The researchers refer to the key role of the teacher to mediate the Logo processes and the fact that the programming activities were based on a structured plan.

The *collaborative* nature of the Logo-tasks is expected to influence the cognitive selection, organization and integration processes (Edwards, 1998). The exchange of e.g., ideas, approaches, strategies, opinions, remarks, solutions, and critiques when developing Logo-projects challenges the individual processing activities. This exchange creates opportunities for the learner to move to the next zone of proximate development (Vygotsky, 1986). Gaßner, Hoppe, Lingnau, & Pinkwart (2003) indicate that it is due to the graphical nature of the Logo as a mindtool that learners can externalize their thinking and enable them to share their "models" they co-construct in the ICT-environment.

In the context of the present study, the model of Gunawardena, Lowe & Anderson (1997) will be used to describe and analyze cognitive processing of the pupils in the collaborative Logo-setting. The instrument is discussed later in this article.

Pupil characteristics and cognitive processing

The literature about the impact of pupil characteristics on cognitive outcomes of instructional interventions is abundant. In the context of ICT-based learning

environments, authors refer e.g., to conceptions of learning, and learning strategies (Salovaara & Järvelä, 2003), perceptions of teaching styles (Shaw & Marlow, 1999; Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998), gender, school environment / learning environments (Buerck, Malmstrom, & Peppers, 2003; Webster & Fisher, 2003), cognitive styles (Buerck et al., 2003), family factors (Supplee, Shaw, Hailstones, & Hartman, 2004), etc.

In this study we focus on two specific characteristics that according to research evidence can be clearly linked to cognitive processing: the cognitive style of the pupils and their gender. As to cognitive style, the conceptual framework has been adopted of Witkin et al. (1977). They distinguish between a *field dependent* and a *field independent* cognitive style. Field-independent (FI) learners are likely to favor domains that emphasize cognitive restructuring skills, and primarily abstract and non-social content. For our research the field independent /dependent cognitive control is useful since it is related to analytical reasoning, formal operational reasoning, and mathematics (Jonassen & Grabowski, 1993).

Recently, Suomala & Alajaaski (2002) found that gender accounted for differences in complex problem-solving processes when a Lego Mindstorms® environment was used. In this study girls demonstrated more cognitive conflict solution processes, more cooperation with teachers and more explicit planning. On the other hand Wang & Ming-Zhang (2003) found that pupils' cognitive style was a significant factor in the demonstration of problem-solving skills among boys but not between girls.

Teacher adoption of constructivist teaching/instructional principles

A clear impact of an ICT-based instructional intervention can only be expected if the use of Logo as a *mindtool* goes along with the clear adoption of specific instructional strategies by the teachers (Swan, 1991). Considering this critical variable is in line with the plea of Lesgold (2000) to consider the teaching variable in researching the impact of educational technology. Also Kulik (2003) stressed this in his recent overview of educational technology evaluation studies since 1990. Studies tend to find more significant changes when teachers are better prepared. The efficacy of the Logo-environment depends on the extent to which teachers address student needs in these environments, ask higher-order questions, provide feedback to problem solutions of students' efforts to solve problems, promote interaction between peers and between teacher and pupils, discuss errors and misconceptions (Clements et al., 1992; Yelland,

2002). Teachers also have to understand the cognitive development of their pupils to foster this development through effective teaching practices (Daniels & Shumow, 2003).

Possible variations in the impact of Logo-use on learning can be due to variations in levels of adoption of social-constructivist instructional principles. In the past, research has hardly controlled for levels of adoption of teaching strategies in studying the impact of ICT and/or Logo. In this study this variable will be controlled as pupils' perceptions.

Research design

Research questions

This study seeks to answer the following questions: (a) What is the impact over time of the Logo-based instructional intervention on the levels of cognitive processing demonstrated by pupils during collaborative problem-solving tasks?; (b) What is the impact of pupils' individual characteristics on the levels of cognitive processing demonstrated by pupils during collaborative problem-solving tasks? (c) What is the impact of the teachers' characteristics on the levels of cognitive processing demonstrated by the pupils during collaborative problem-solving tasks?

In view of answering these questions, the following hypotheses have been put forward:

1. IEPSE-pupils show higher mean levels of cognitive processing compared to pupils that did not participate in the Logo-sessions.

2. Pupils characteristics (cognitive style and gender) interact with the levels of cognitive processing demonstrated during the group activities.

3. There is a positive relation between the average perception of the pupils about their teachers' adoption of social-constructivist teaching principles and the level of cognitive processing of the pupils.

4. IEPSE-Pupils demonstrate higher levels of cognitive processing in 2003 as compared to 2002.

Research approach

A quasi-experimental design was implemented with a random assignment of school classes and their teachers to two experimental and one control condition. In view of testing the hypotheses, non-participant observation, a cognitive style test and questionnaires have been used. Non-participant observation assures the collection of rich data about the actual process of cognitive processing in a collaborative environment. Collaborative activities were observed and video-recorded and next analyzed using the Gunawardena, et al. model. The Group Embedded Figures Test (GEFT) was used to identify the cognitive style of the pupils (Witkin, Oltman, Raskin, & Karp, 1971). Pupils were asked to fill out the Constructivist Learning Environment Survey (CLES, Taylor et al., 1997). The information drawn from the CLES helped to determine pupil's perception of levels of social-constructivist instructional principles demonstrated by the teachers in their classes.

Research sample

Eight fifth-grade classes and their teachers were involved in the study: 3 IEPSE-classes whose teachers had been enrolled in the IEPSE-training (experimental condition A), 3 classes from IEPSE-schools whose teachers had not participated personally in the IEPSE-teacher training (experimental condition B) and 2 classes that were not in the IEPSE-project and whose teachers did not receive training (control condition). Classes in the study were selected on the base of their teachers being/or not being in the project or having received training. All teachers participating in the study work in rural schools of the Peninsula region; they are 45 years-old in average; they have a diploma in primary education; they did not follow post-graduate studies; they did not have previous experience with ICT; and only two of them are female. These teacher characteristics are comparable to the average coastal region teacher in the Santa Elena Peninsula (Chiluiza-García & Valcke, 2004b). A stepped sampling procedure was followed to select the eight teachers. At a first stage, 43 schools were selected randomly from the total number of public schools in the Peninsula region (*N*=137). Due to resource constraints, 20 schools were selected from this sample to be involved in the IEPSE-project. This selection was based on the extent to which schools were able to invest time in the project and whether teachers were able to follow the training linked to the project. From the 20 schools included in the IEPSE-project, 6 fifth-grade teachers of six different

schools were selected ad random (using code assignment) to be involved in this study. Three IEPSE-teachers that personally have been enrolled in the IEPSE-training (experimental group A), and three teachers of schools enrolled in the IEPSE-programme but who did not participate personally in the training (experimental group B). Next, three fifth-grade teachers were selected ad random from the 23 schools that were – yet - not included in the IEPSE-project. Only 2 teachers answered positively to the request. A further selection and invitation -to get a group of 3 teachers in control group- did not yield positive results; thus control group only consist of two teachers and their classes.

Pupils in the study attend rural public schools, which are not advantaged in terms of teacher number or infrastructure. The villages where these schools are located are very similar as to demographic indexes such as: illiteracy (11%), poverty (78%), primary school completion (64.7%), secondary school completion (12%), and so forth (COSASE, 2002).

The total number of pupils in the 8 classrooms was 249. As to the video analysis of the collaborative work of the pupils, a sub sample of 2 x 4 pupils was randomly selected from the group of pupils in each class. This is explained in more detail in the research procedure section.

The quasi-experimental treatment in the IEPSE-project

The sessions for the pupils in the experimental condition A and B, started August 2000 as extra-curricular activities, with a focus on ICT literacy topics. At this stage of the project none of the pupils were acquainted with computers or keyboard use. In the next stage, from April 2001 until January 2002, IEPSE pupils attended classes where collaborative activities were organized based on Mindstorms® and Logo Microworlds®. In the next school year, starting April 2002, pupils continued with the activities in the same technological environments and also as extra-curricular lessons. In the school year starting April 2003, pupils continued this training during regular school hours. Important to notice is the fact that even though the attendance to this training was not compulsory for pupils, the complete classes attended the sessions.

In the IEPSE-project, sixteen to twenty pupils attended the Logo-sessions at the same time in the computer labs. These labs were organized on a two-weekly base. During a school year (10 months), pupils worked for about 20 hours with the computers. The teachers, supporting the sessions, were regular school teachers, who on

average worked 10 hours a week in the ICT-laboratory. For the purpose of this study we focus on the learning activities during the school years 2002 and 2003 and the learning activities of a sample of 5th grade classes (all of them are between 11 and 12 years old in 2003). The activities of these pupils in the project were based on the *mindtools* and implied e.g., planning, programming, testing procedures, use of buttons, influencing turtle behavior, debugging programmes, and making presentations of their projects to other peer groups, the school and local educational authorities. Pupils worked in dyads to develop the Logo-projects. The teacher put forward the general theme of the project, but pupils were completely free to elaborate the projects in their own way. Most project themes built on topics discussed in the normal classroom. Typical themes were related to natural sciences, social sciences, language and mathematics. Figures 1 to 4 illustrate typical IEPSE-activities and projects.

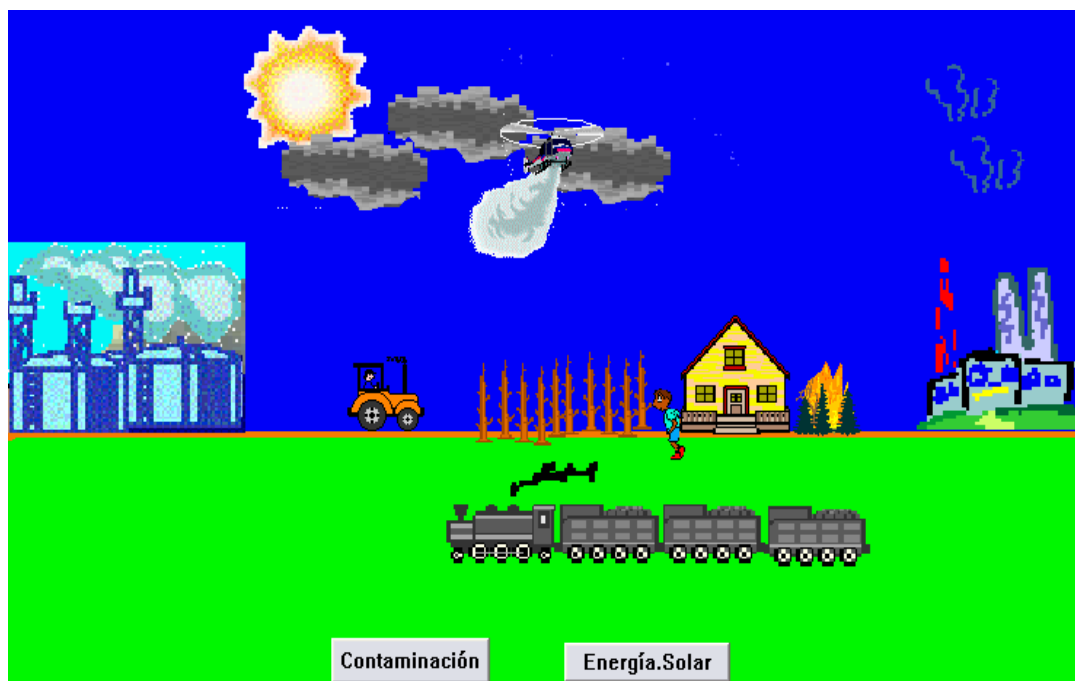*Figure 1*: Project about Dengue fever, prepared by pupils of 5th grade (year 2002)

Figure 2: Project about contamination and its effects developed by pupils of 6th grade (year 2003)

Figure 3: IEPSE pupils while working in a project

Figure 4: IEPSE pupils explaining part of their project

Research variables and research instruments

Levels of cognitive processing

As was explained before, information about the levels of cognitive processing was gathered through observation and analysis of video recordings of the group work at the end of the school year 2002 and at the end of the school year 2003.

In view of determining the levels of cognitive processing, the model of Gunawardena, Lowe & Anderson (1997) was used. This model has proven to effectively identify and determine knowledge co-construction; though, in different subjects and environments (Schellens & Valcke, 2004). Gunawardena and her colleagues emphasize that two kinds of knowledge are created inevitably when sharing learning experiences, *individual knowledge* and *social knowledge*. Each member of the group creates his/her own knowledge at the individual level and the social knowledge is created at the level of the group. The group evolves in this co-construction of knowledge. They developed the model in the context of studying knowledge construction in computer-supported collaborative learning environments. Five phases or levels of co-construction of knowledge are identified: (a) level 1: sharing/comparing (observation, agreement, corroboration clarification and definition); (b) level 2, inconsistency/dissonance (identifying and stating, asking and clarifying, restating and supporting); (c) level 3: negotiating what is to be agreed/co-construction (proposing new co-constructions that comprehend the negotiated resolution of differences); (e)

level 4: testing tentative constructions (the new constructed statements of ideas are tested, and matched again to personal understandings and other resources); (f) level 5: statement/application of newly constructed knowledge (final revision and sharing again of the new ideas that have been constructed by the group).

We give some examples of the phases of knowledge co-construction:

Level 3 (negotiating what is to be agreed/co-construction)

Student A: "We don't need to pay the full-ticket price….. We are children!"

Student B: "No, you're not right … (re-reading instructions)"

Student C: "Yes, he's right… (pointing-out a note in the instructions)"

Student A: "Yes….if we do like that… we will save some money!"

Student B: "Ok, it's ok"

Level 5 (statement/application of newly constructed knowledge)

Student B: We finished!

Student C: Why don't we check first? Check!

Student A: "Oh oh… There's a technical error"

Student B: "Let's check, hey let's check!" (grabbing one arm of C)

Students A, B, C: (reviewing the arithmetical operations)

Student B and C: "It was ok!"

Student C: "Give it to the miss"

The video recordings were analyzed by a group of three independent researchers. They received a training to work with the model of Gunawardena et al., (1997) in order to reach high interrater reliability. Each video recording was analyzed in time-frames of 2 minutes. The highest level of cognitive processing observed in each pupil in each time frame was coded. All recordings were observed and analyzed simultaneously by the researchers. At the end of each session, the coding was compared and its quality was assessed by determining *Cronbach α*. A value of 0.7 was put forward as a criterion for interrater reliability. The α values for the different discussions varied from .82 to .99 for year 2002 and from .79 to .98 for year 2003. To control for systematic differences in coding, the coding session was extended with a discussion about the differences in coding. This approach has been found to be useful to assure consistency (Stemler, 2004). The approach followed could result in some minor changes in coding by a coder. After this discussion phase interrater reliability was recalculated (between .91 and .99 for both years). To check whether it was not always the same

researcher changing the coding category, *Cronbach* α was also calculated for each individual researcher, resulting in an α coefficient between .75 and .99 for both years.

Pupils characteristic: cognitive style

As was stated earlier, data about cognitive style was gathered at the start of the procedure (*N*=241) and with the Group Embedded Figures Test (GEFT) of Witkin et al., (1971). The reported Spearman-Brown coefficient for this instrument is .82. In the present study reliability was recalculated and resulted in very high (α = .90).

Pupil's perception about the social-constructivist instructional strategies demonstrated by their teachers

The Constructivist Learning Environment Survey – CLES (Taylor et al., 1997) evaluates the perceived constructivist environment fostered by teachers in science classes. The 25 items represent five subscales: personal relevance (PR), uncertainty (UN), shared control (SC), critical voice (CV), and student negotiation (SN). PR refers to the perceived relevance of what pupils learn at school related out of school experiences and how teachers build on experiences of pupils. UN corresponds to the extent to which opportunities are provided for pupils to experience knowledge as arising from personal experience and values, and as culturally and socially determined. SC reflects the extent to which pupils share control of their learning environment with the teacher. CV represents the extent to which students feel that it is rightful and positive to question their teacher's plans and methods, and to express their concerns to others about learning. SN assesses the extent to which pupils explain and justify their ideas to others, appreciate each others ideas and reflect on their viability. Teachers and pupils react to each item on a Likert scale (1 = never to 5 = always). The reported Alpha-reliability coefficient for this tool is between .90 and .85 (Lee & Fraser, 2001; Puacharearn & Fisher, 2004).

Pupils were invited to fill out the CLES questionnaire in 2003. Overall reliability of the test is α =.73. The CLES was also administered in 2002, but the data were incomplete and unreliable and therefore excluded from the analysis.

GEFT, CTI and the CLES were translated from their original version into Spanish, using translation and back-translation method of Behling & Law (2000). The Spanish versions were pilot tested using a small sample of pupils and teachers to ensure their clarity and legibility. These pupils did not participate in the further study.

Procedure

This study started April 2002, one year after the initial start of the IEPSE-project with *mindtools* with the pupils and lasted for two school years. The GEFT and the CLES were administered from all pupils. At more general level information about age, gender and background information was gathered from the pupils. After this pre-testing phase, the pupils in the experimental condition continued working with the Logo-*mindtools*.

At the end of the school year 2002, 2 groups of 4 pupils (2 girls/2 boys) were selected at random from each of the eight classes. These groups were asked to carry out a collaborative problem-solving task. The group task was based on task specifications of Joyce, Calhoun & Hopkins (2002). In this task, each group had to plan a trip or a reunion, based on role play. Pupils decided which role was best to reach the goals. The task incorporated rules, a minimum budget, constraints about places to visit, places to buy necessary items, and it included a clear documentation of the steps the pupils had to follow for reaching the goal, next to a clear description of the final task requirements. The collaborative work of each of the 16 teams was video taped. The session lasted about one hour.

The same procedure was followed at the end of the school year 2003. The same eight teams were asked to carry out a collaborative group task. Some pupils who participated in the 2002 and were not enrolled in school year 2003 were replaced by other pupils. Again their work was video taped.

Statistical analysis

Statistical analysis for this study is based initially on descriptive statistics. The non-parametric tests Chi-square, Kruskall-Wallis, Mann-Whitney U and Wilcoxon paired tests were used to compare mean levels of cognitive processing demonstrated by pupils from different conditions. Logistic regression was used to test hypothesis 3 instead of linear regression. A requirement for linear regression is to include a large number of observations. This was not the case of this study. Secondly, the criterion variable in this study is dichotomous (high or low level of cognitive processing).

Results

Table 1 summarizes the distribution of the proportions of different levels of cognitive processing as observed in the pupil interactions at the end of both school years. The number of interactions was higher in school year 2003. There are obvious changes in the distribution of the proportions observed when comparing both school years.

Table 1. Distribution of proportions of levels cognitive processing in collaborative tasks based on Gunawardena et al. (1997) for 2002 (*N*=870) and 2003 (*N*=1147)

	Group	Phases in cognitive processing %				
		Level 1	Level 2	Level 3	Level 4	Level 5
Year 2002	Experimental A	74.3	2.0	17.3	6.5	-
	Experimental B	66.5	-	23.2	9.7	0.6
	Control	83.4	-	11.7	4.9	-
	Total	73.6	0.7	18.2	7.4	0.2
Year 2003	Experimental A	97.4	0.9	1.3	0.2	0.7
	Experimental B	94.7	1.3	3.8	-	0.3
	Control	100.0	-	-	-	-
	Total	97.1	0.8	1.7	0.1	0.3

The median for school year 2002 and 2003 was used to distinguish between pupils demonstrating a high or a low mean level of cognitive processing (see table 2). This categorization revealed even numbers of pupils in each category in 2002. But the proportion of pupils attaining a higher cognitive processing level is lower in 2003 (22%). Interestingly, only pupils in the experimental conditions reached such higher levels; though, the proportion within these conditions also decreased. This categorization is used when testing hypothesis 3.

Table 2. Percentage of pupils demonstrating low or high levels of cognitive processing in 2002 and 2003 (*N*=64)

Group	LCP – 2002		LCP – 2003	
	Low	High	Low	High
Experimental A	42%	58%	75%	25%
Experimental B	54%	46%	67%	33%
Control	56%	44%	100%	-
Total	50%	50%	78%	22%

Pupils (*N* = 241) were classified according to their cognitive style in field dependent (FD=24%), field dependent/independent (FDI=35 %) and field-independent (FI=41%). This pupil characteristic is of importance in testing hypothesis 2.

Hypothesis 1: IEPSE-pupils show higher levels of cognitive processing compared to pupils that did not participate in the Logo-sessions.

First we test whether the proportions of different levels of cognitive processing are equally distributed. Analysis of the descriptive data presented in table 2 already suggests that no equal distribution is observed in the three conditions. This is confirmed by the Chi-Square analysis for year 2002 for the experimental condition A and B χ^2 (3) = 1164.90, *p*<.001; experimental condition A and control χ^2 (2) =7.21, *p*<.05; experimental condition B and control χ^2 (2) = 27.44, *p*<.001. The differences in distribution in 2003 are confirmed by the Chi-Square analysis between experimental group A and B χ^2 (3) = 38.98, p<.001. It was not possible to test differences in distributions for the control condition mainly because this group demonstrated level 1 cognitive processing. In both school years cognitive processing level 1 (sharing and comparing information) is predominant, followed by level 3 (negotiation of meaning/co-construction of knowledge). Some level 4 behavior (testing/modification of proposed co-construction) is observed in year 2002, but this is hardly observed in 2003. Interaction at level 2 (dissonance/inconsistency in ideas) and level 5 (application on newly constructed meaning) almost never occur (especially not in year 2003). In both school years, pupils in the control condition do not reach level 5, whereas pupils in the experimental condition B reach level 5 in both school years and pupils in experimental condition A only reach level 5 in year 2002.

The Kruskal-Wallis test is used to compare mean levels of cognitive processing between pupils in the different conditions. We notice no significant differences between the three conditions in year 2002. However, when applying the same test on the data from 2003, a significant difference is observed between the conditions χ^2 (2) =7.29, *p*<.05. Further analysis using the Mann-Whitney U test helps to identify significant differences between the experimental B and control condition *Z*=-2.72, *exact p*=.002 (1-tailed) and meaningful differences between the experimental A and control condition *Z*=-2.72, *exact p*=.096 (1-tailed). Based on these results, the null hypothesis can be rejected. IEPSE-pupils demonstrate higher levels of cognitive processing.

Hypothesis 2: Pupils characteristics (cognitive style and gender) interact with the levels of cognitive processing demonstrated during the group activities.

To test this hypothesis a Kruskal-Wallis test was applied. Three types of cognitive style were considered: FD, FDI, and FI. It was found that there are significant differences for the three conditions in year 2002 χ^2 (2) = 6.30, $p<.05$ and in year 2003 χ^2 (2) = 8.73, $p<.05$. The results of further analyses using the Mann-Whitney U test are presented in table 3. Based on these results, the null hypothesis can be rejected. Pupils with a FI cognitive style demonstrate higher levels of cognitive processing. In addition the gender condition was also tested for hypothesis 2, using the Mann-Whitney U test. The mean levels of cognitive processing are not significant in any of the two conditions in year 2002 ($z = -1.42$, *exact p* = .156, 2-tailed) nor in year 2003 ($z = -1.57$, *exact p* = .117, 2-tailed).

Table 3. The relationship between levels of cognitive processing and cognitive style (hypothesis 2)

Dependent variable	Z score for multiple comparisons
Mean LCP year 2002	FD-FDI (-0.09)
	FD-FI (-2.05) *
	FDI – FI (-2.10) *
Mean LCP year 2003	FD-FDI (-0.17)
	FD-FI (-2.13)*
	FDI – FI (-2.40) *

*$p<.05$

Hypothesis 3: There is a positive relation between the average perception of the pupils about their teachers' adoption of social-constructivist teaching principles and the level of cognitive processing of the pupils.

A logistic regression analysis was performed with level of cognitive processing (high/low) as the dependent variable and average perception of pupils about the adoption of social-constructivist teaching principles by their teachers (CLES-scores pupils' version) as the predictor variable. A total of 60 cases were analyzed and the full model was significantly reliable in the omnibus test (χ^2 (1) = 8.18, $p=.004$). This model accounted for between 12.7% and 19.6% of the variance, with 97.9% of pupils in the low level cognitive processing category successfully predicted. However, only 23.1% of predictions for the high level cognitive processing category group were accurate.

Overall 81.7% of predictions were accurate. The values of the Wald statistic for the predictor variable is 6.74 (p=.009). The estimated logit is Log [p/(1-p)] = -9.6 + 0.092*CLES-pupils' version. The coefficients (B= 0.092 and $Exp(B)$ = 1.10) show that each unit increase in the perception of pupils about their teachers adoption of social-constructivist teaching is associated with an increase in the odds of falling in category high of cognitive processing by a factor of 1.10. Even though the model is significant we prefer not to draw a conclusion about this hypothesis -given the small number of high level cognitive processing behaviors used to build the model.

Hypothesis 4: IEPSE-Pupils demonstrate higher levels of cognitive processing in 2003 as compared to 2002.

We first test whether the distributions of levels of cognitive processing were equal when we compare the 2002 and 2003 results. Data from table 2 suggest some changes. These changes look different depending on the research conditions. Pupils in the experimental condition A reflect more level 5 cognitive processing; but only marginally. Chi-Square test indicates that the differences are significant: χ^2 (4) = 19885.03, p<.001. This looks to be especially due the lower proportion of level 3 and level 4 cognitive processing. The experimental B condition shows a decrease in level 3 and 5, and no level 4 cognitive processing in school year 2003. This change is confirmed by the Chi-Square test. The differences are significant: χ^2 (3) = 57385.12, p<.001. It was not possible to run a Chi-square test for the changes in proportions of the pupils in the control condition because only level 1 cognitive processing has been observed.

A Wilcoxon-paired test was used to test mean differences between 2002 and 2003 in all conditions. The results of the test corroborated the previous results. There is a significant difference in the levels of cognitive processing over time, though the final levels of cognitive processing are lower in year 2003 than the ones reached by the students in year 2002 (Z=-4.68, *exact p*<.001, 1-tailed). Based on these results, we cannot reject the null hypothesis.

Discussion

The aim of this study was to answer the following question: What has been the impact over time of the IEPSE project and the following changes in learning environments on the actual cognitive processing of pupils? In view of answering this main question four different hypotheses were tested. In the next paragraphs, the discussion will be structured along these hypotheses.

In general, there are clear differences in the distribution of proportions of cognitive processing levels. We observe mainly cognitive processing at level 1 (sharing and comparing) and level 3 (negotiation and co-construction) of the model of Gunawardena et al. (1997). We hardly observed level 4 and 5 cognitive processing. These results are similar to the results of Schellens & Valcke (2004, in press) who - when analyzing asynchronous electronic discussions- also found that level 1 and 3 behavior are pre-dominant. They suggested that this could in part be due to the nature of the analysis scheme. In the present study, also the predominance of contributions at level 1 is of importance. This coincides with the results of earlier studies that applied the same analysis model in CSCL environments (De Wever, Van Winckel, & Valcke, 2004; Gunawardena, Lowe, & Anderson, 1997).

The analysis of data gathered in 2002 does not reflect significant differences in levels of cognitive processing between pupils in the three research conditions. But, one school year later, IEPSE-pupils demonstrated a small but significant change in the distribution of proportions of levels of cognitive processing. These results are in line with findings of other researchers regarding the capabilities of Lego/Logo software on the development of cognitive skills and positive cognitive processing effects (Suomala et al., 2002; Yelland, 2002; Clements et al., 1999; Morrison et al., 1999; Nastasi et al., 1994; Nastasi et al., 1992; Many et al., 1991). Other researchers were less successful to detect significant changes and are not in line with the current findings (Dicheva, 1996; Pea & Kurkland, 1984).

Pupil characteristics were studied as to their interaction effects on the cognitive processing in the collaborative tasks: gender and cognitive styles. Gender did not affect the cognitive processing levels in the different conditions. But, cognitive style has a significant impact. Field independent pupils reached higher levels of cognitive processing as compared to field dependent pupils. These results are related to the findings of other researchers in the sense field independent pupils are likely to

emphasize cognitive restructuring skills as the ones measured in this study (Heller, 1982; Jonassen et al., 1993).

The average adoption of social-constructivist teaching principles was also measured by asking the pupils to rate their teachers. A pupil version of the CLES was administered for this purpose. The data helped us to build a predictive model. The model resulted significant and overall predicted more than 80% of the dependent variable; it shows that the higher the perception of pupils about the average adoption of social-constructivist teaching by their teachers, the higher the odds pupils are categorized in a high level of cognitive processing. However, given the small number of behaviors of pupils in this cognitive processing category, we cannot draw a definite and clear conclusion. Moreover, the lack of other measures of the same construct e.g., based on structured interviews, or a forum discussion, or an analysis of the actual teaching behavior of the teachers would help to a larger extent to reach to stronger conclusions (Lee et al., 2001). In addition, the small sample size used for this analysis is another weakness of this part of the study. Sample sizes have affected the statistical analyses used in the study and have obliged the researchers to opt for methods –logistic regression and consequently the use of categorical variables- that lower the power of these analyses.

The analysis of impact over time of the IEPSE-project on pupils' levels of cognitive processing was also less clear. At a general level, the proportion of higher levels of cognitive processing has hardly changed in 2003 as compared to 2002. The majority of the contributions reflected level 1 cognitive processing. But the pupils in the experimental conditions still reflected behavior in relation to all levels in the model. In contrast, the pupils in the control condition only reflected behavior coded as level 1 in the model of Gunawardena et al. (1997) in 2003. There is hardly comparable and recent research available to contrast or discuss these results. Most Logo-related studies were set up in 80s and 90s. In some studies, researchers found positive long term impact of Logo on cognitive processing (e.g. problems solving, planning behavior, monitoring behavior), whereas other studies did not report significant changes (see for an overview Chang, 1989; De Corte, 1993; Valcke, 1991).

In the present study, a near transfer task was presented to all pupils in the three conditions. Kynigos (1989) also reported difficulties in detected transfer of a possible Logo-impact. Only Verschaffel et al. (1990) could report clear and significantly positive results on near-transfer task. Analysis of their research design explains why the current

study was maybe less successful to detect significant changes over time. A smaller group of 24 pupils received an intensive training in Logo (over 60 hours) and especially designed problem solving training, besides the one received in the Logo environment (see also for related research McCoy, 1996). The latter was not the case in the present study. Normal classroom content related to the topics dealt with in natural sciences, geography, or mathematics was dealt with. In this way, a more fair comparison with the other research conditions could be guaranteed. Although the pupils also worked with the Logo-environments for about 60 hours, this was during a much longer period of time and with intermittency due to e.g., a long teachers' strike in the Ecuadorian school setting at end of the school year 2003.

The number of variables and processes measured and controlled for in this study was large. But given the quasi-experimental nature of the study, this number is still limited to be able to account for the impact of all variables that affect teacher and pupil behavior. As stated earlier, also other variables internal and external to pupils are known to have a large impact on their cognitive processing. Critical variables not considered in this study are e.g. the ICT-experiences of the pupils in the control condition, the school environment, pupils' beliefs about learning, and ICT, participation of parents, and ICT-skills of the pupils. Future research should also consider involving a larger sample of pupils and more classes/teachers.

Conclusions

What has been the long term impact of the IEPSE project on the actual cognitive processing in 5th grade pupils? It can be concluded that a marginal positive impact of the IEPSE project could be detected in relation to the attainment of slightly higher levels of cognitive processing by pupils in the experimental conditions. But the impact remains restricted and this made it not possible to test in a clear way whether this could be related to the adoption of social-constructivist instructional principles by the teachers, as perceived by the pupils. The results were clear as to the significant interaction of cognitive style with levels of cognitive processing.

But, more research is needed to be able to generalize the findings. Moreover, in future research methodological limitations have to be deliberated. Future research should pay closer attention to instructional variables in the teacher, the pupils and the task that could account for higher or lower cognitive processing. Next, also variables internal and external to the pupils and teachers should be considered and measured to

account for differences between conditions and determining the adoption of new teaching strategies.

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Chapter 4

Logo as a mindtool: the impact on mathematics learning of 5th grade pupils in Ecuador[*]

Abstract

This quasi-experimental study researched the question: What is the impact of Logo-mindtools and constructivist teaching strategies on mathematics learning outcomes of 5th grade pupils? The study was set up in the context of an evaluation of the Ecuadorian IEPSE-project involving eight 5th grade classes. The results reveal a meaningful impact over time on mathematics scores. The learning impact is related to cognitive style and not related to gender. No interaction effects with teaching strategies could be observed. A strong significant interaction effect with levels of cognitive processing was detected. Limitations of the study and directions for future research are presented.

Introduction

The present study researches the impact of a computer-based learning environment in primary schools. The research is linked to the evaluation of the Innovation of Education in the Santa Elena Peninsula project (IEPSE) set up in Ecuador. This project focuses on teachers to promote the adoption of social-constructivist teaching principles such as active learning, self-reflection, and collaborative learning in their daily classrooms. In this context, teachers used Lego Mindstorms® and Logo Microworlds® as *mindtools* to support the learning process of their pupils. Part of the project evaluation researched the impact of the new approach on the acquisition of mathematics of 5th grade pupils (10 years old) for a two-year period. This brings us to the central research question of this study: What is the impact over time of the IEPSE project – the use of the Logo-mindtools and the changes in teaching strategies - on the mathematics learning outcomes of 5th grade pupils?

In this article, we first describe the IEPSE project. Next we discuss the theoretical and empirical base in relation to dependent, independent and intervening

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variables in the study. On this basis the hypotheses and the research design are put forward. After presentation and discussion of the results, directions for future research are specified.

The IEPSE project

Background

The limited amount of information available to educational policy makers about the quality of teaching and learning in Ecuadorian schools points at critical issues in relation to the mastery of mathematics skills. The results of the APRENDO-tests that have been administered nation-wide in 1996, 1997 and 2000 point consistently at rather weak mastery levels. For instance, in the year 2000 approximately 64% of the 2nd grade pupils were qualified at beginners' level, 20% at advanced/intermediate level and only 16% at master level. In the sixth grade, 84% of the pupils were qualified at beginners' level, 12% at advanced/intermediate level and only 4% at the master level (MEC, 2002). Notwithstanding these critical results hardly efforts have been put in the innovation or reformation of education in Ecuador. But considering the difficult political, social, and economical context in Ecuador, it is no wonder that the latest educational reform of 1992 has hardly been implemented until now.

During the last five years, an Ecuadorian university, the Escuela Superior Politécnica del Litoral, has implemented a pilot project to innovate primary education in Ecuador through the use of information and communication technologies (ICT). The IEPSE project consists of several components: (a) an in-service teacher training program, (b) deployment of computer labs with internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and instructional support for teachers trained in the program. 20 primary schools, 40 teachers and nearly 8,000 pupils from first to sixth grade (6-11 years old) were initially involved in the project. Currently, more than 43 schools are part of the IEPSE-network and more than 10,000 pupils are expected to be influenced.

Characteristics of the IEPSE teacher training

IEPSE teachers were trained to adopt social-constructivist instructional principles in their classrooms while integrating ICT tools into their teaching. Constructivist learning is characterised by involving learners in situated and authentic activities that mirror the real world (Duffy & Jonassen, 1992). Learning is active (manipulative), constructive (articulative), intentional (reflective, regulatory), authentic (complex, contextualized), and cooperative, collaborative, conversational and socially negotiated (Bednar, Cunningham, Duffy, & Perry, 1992; Driscoll, 2000; Jonassen, Howland, Moore, & Marra, 2003; Schunk, 2004). Several methods of instruction that foster conditions for constructivist learning have been suggested e.g., the use of microworlds, problem-based learning, collaborative learning, hypermedia, open-ended learning environments, etc. (Driscoll, 2000).

The IEPSE training helped to experience hands-on the above principles about learning and instruction. The teachers were also trained to master the didactical strategies that promote constructivist learning. The IEPSE teachers learned to design complex, relevant and contextual tasks that are to be tackled in a collaborative way by the pupils. These tasks involve the use of mindtools, such as Logo-Microworlds® and Lego Mindstorms®. These tools are considered to be *mindtools*, since they are in line with the definition of Jonassen: (a) the ICT-application can be used to represent knowledge; (b) the experience is generalizable to content in different subjects (in this case mathematics, sciences, geography, etc.); (c) it engages learner in critical thinking about the subject; (d) it develops skills transferable to other subjects; (e) it significantly restructures or amplifies thinking and (f) it is learnable in 2 hours or less (Jonassen, 1996; Jonassen et al., 2003).

As is the case in most constructivist teaching approaches, instructional strategies are based on collaborative learning and problem-based learning. The didactical strategies – developed in the IEPSE teachers - helped pupils to engage in social negotiation and to explore multiple ways to look at and to solve problems.

The ICT-based learning environment: Logo

The research literature is clear about the potential of ICT as a tool and catalyst to foster learning. ICT is projected and expected to help to create, collect, store, and use newly

built knowledge and information. Review studies and individual research reports suggest that the use of ICT promotes the development of skills needed in the information society, such as thinking skills and problem solving skills. ICT is also positively associated with student achievement in a variety of knowledge domains, e.g., mathematics (Cox et al., 2004; Mc Guiness, 1999; Murphy et al., 2002; Schacter, 1999; Valdez et al., 2000; Waxman, Lin, & Michko, 2003).

The Logo-programming language was developed as a tool to foster the collaborative construction of knowledge (Papert, 1980). The potential of Logo has been extensively studied and researched in the 80's and the early 90's. Most of this research focused on measuring learning outcomes such as mathematics and geometry, the demonstration of metacognitive skills and cognitive skills, next to a strong focus on the acquisition of Logo- programming skills (Chang, 1989; Valcke, 1991). The following was identified as valuable cognitive outcomes of Logo-use: higher levels of mathematical thinking (especially geometric thinking), a more generalized and abstract view of mathematical objects, a deeper conceptualisation of fundamental concepts in geometry, and the development problem-solving skills (Cathcart, 1990; Chang, 1989; Clements, 1990; Clements & Nastasi, 1992; Enkenberg, 1990; Hoyles & Noss, 1990; Many, Lockard, Abrams, & Friker, 1991; Nastasi & Clements, 1994; Nastasi & Clements, 1992; Swan, 1991; Verschaffel, De Corte, & Schrooten, 1990).

But despite the moderate positive claims about the cognitive effects of Logo, research also points at problems with transfer of learning gains to other knowledge domains or contexts (Dicheva, 1996). It has been argued that the benefits of Logo and the transfer of skills acquired in Logo-based learning environments, were only to be expected after the pupils worked and learned with the environment for at least a year (Clements & Meredith, 1992). The actual time spent in practicing high-level thinking skills and the frequency of this practice mediated by Logo has been found crucial to further develop and transfer the skills (Morrison, Cowan, McBride, & McBride, 1999). This will be considered in the study, discussed in this article.

The original Logo-studies have been criticized as to a number of methodological shortcomings. Too many studies were set up in artificial laboratory contexts (Verschaffel et al., 1990). Next, the findings of studies were very inconsistent and not replicable, in part due to weaknesses in the research reports, e.g., lack of clarity, lack of conceptual precision, incomplete reports, too small sample sizes, the presentation of anecdotal evidence, and a high teacher/student ratio (Valcke, 1991; Wyatt, 1988). These

issues limited the generalization of the findings. There was a clear need for a re-orientation in Logo research. Authors called for research of learning environments in more authentic school settings (Suomala, 1999). De Corte (1993) underscored, as a result of his research review, that successful future Logo-studies should incorporate at least the following aspects: (a) a good balance of discovery learning with good systematic mediation and instruction; (b) direct instruction in problem-solving skills within the Logo context; (c) a focus on specific skills to be developed (and a focus on measurement of these skills as a result of the Logo-experience) and (d) the adoption of cognitive apprenticeship teaching approaches.

But the number of Logo-studies suddenly decreased and the research virtually stopped at the beginning of the 90's. This is probably related to the too high implications of the projected integrated Logo-use in schools. For instance, the computer/pupil ratio was at that time inadequate. Other limitations were related to the other implications of integrated Logo-use, such as the need for curriculum development, teacher training, the underlying educational philosophy and rigid characteristics of the school system (Valcke, 1990). Logo-use entails the revision and expansion of traditional activities to incorporate objectives about higher-level thinking processes (Hoyles et al., 1990; Clements et al., 1992). Another apparent reason for the decrease in Logo related research is the advent of the Internet and the possibilities this opened for a reorientation in technology related educational research.

The perspective introduced by the concept *mindtools* has reanimated the use of microworlds and Logo-based environments and related research to this topic. Newer versions of Logo-based learning environments have come available, and the software and technology have become more readily available in schools. We argue that it is therefore the right moment to research again the potential of Logo-based environment, but now taking into account methodological critiques on Logo and educational technology evaluation studies in general: (a) a focus on impact over time, (b) studies in naturalistic settings, (c) measurement of the impact on near-transfer tasks, (d) and control of instructional variables (see e.g., Haertel & Means, 2000 and Rumberger, 2000). A key element in this context is a shift in focus from outcomes measurement to process analysis of the outcomes of learning with Logo.

The research variables in the present study

Mathematics

The main dependent variable in the present study is the mathematics learning outcomes of the 5th grade pupils. The use of Logo-based learning environments fits into the most recent approach towards the teaching and learning of mathematics: the realistic mathematics education (RME). The RME approach is characterized by its use of contexts, pupils' productions and constructions, and interaction between teachers and pupils (Treffers, 1987). Technological tools are considered as supportive tools where students use them as an alternative for routine work, to support learning through visualization of a concept and that support investigative work when solving problems related to real-life situations (Van der Kooij, 2000; van den Heuvel-Panhuizen, 1998). Others researchers also point out the importance of situated cognition in mathematics teaching and learning or the connection between theory and actual settings (Brown, Collins, & Duguid, 1989).

De Corte (2000) describes in another way the relationship between Logo and mathematics learning. He stresses an approach of mathematics instruction based on power learning environments. Learning environments support the transfer of newly acquired knowledge to new settings, engage pupils in constructive goal-oriented processes, foster self-regulation, stress learning with authentic and real-world problems, and stress metacognitive skills. The impact of Logo and learning environments is both at the level of complex higher order skills, deep conceptual (mathematical) understanding, and metacognitive capabilities. Also other authors point at this link between Logo and mathematics learning (Jonassen & Marra, 1994; Jonassen, Carr, & Yueh, 1998). The *mathematical knowledge objects* that can be programmed with Mindstorms® and Logo Microworlds® can easily be linked to the prior knowledge and function as *objects-to-think-with*. With these objects, pupils can create and re-create mathematics-related situations linked to real-life settings.

In the former section, we already presented research evidence about the impact of Logo on mathematics learning. The cognitive and metacognitive outcomes, such as problem representation, strategies monitoring, etc. are linked to the conceptual understanding of mathematics, arithmetic skills and problem solving (Cohen, 1996; Mayer, 1985; Mayer, 1999; Rittle-Johnson & Alibali, 1999). In the present study, we study the impact of learning with Logo on mathematics learning, but will also consider

the mediating impact of cognitive processing while solving problems in collaborative settings.

Logo, cognitive processing and knowledge co-construction

An intervening variable in this study is the level of cognitive processing demonstrated by pupils while solving collaboratively problems. The impact of Logo on mathematics is hypothesized to be dependent on levels of cognitive processing fostered by the Logo-activities. The direct impact of the Logo-learning environment on cognitive processing has been researched and reported in a previous study (See Chiluiza-García & Valcke, 2004a). At a theoretical level, the assumptions about the impact on cognitive processing are based on the information processing cognitive theory (Atkinson & Shiffrin, 1968; Atkinson & Shiffrin, 1971), cognitive load theory (Mayer, 1996; Sweller, 1994; Sweller, 1988) and the social-constructivist learning hypotheses (Vygotsky, 1978). Also other Logo-studies reported a positive influence on the development of higher cognitive and monitoring skills (for a review see Clements et al., 1992). In the present study, the model of Gunawardena et al., (1997) has been used to describe and analyse cognitive processing of the pupils in the collaborative Logo-setting environment. This model has been developed following a grounded theory approach. It proposes a – hierarchical - typology to evaluate knowledge construction through social negotiation. Observation of higher levels of cognitive processing in collaborative learning contexts is expected to result in higher mathematics scores.

Pupil characteristics

The literature about the impact of pupil characteristics on learning outcomes of instructional interventions is abundant. In the context of ICT-based learning environments, authors refer e.g. to conceptions of learning, and learning strategies (Salovaara & Järvelä, 2003), perceptions of teaching styles (Shaw & Marlow, 1999; Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998), gender, school environment / learning environments (Buerck, Malmstrom, & Peppers, 2003; Webster & Fisher, 2003), cognitive styles (Buerck et al., 2003), family factors (Stuart, 2000; Supplee, Shaw, Hailstones, & Hartman, 2004), students self-perceptions (Trusty, 2002; Trusty & Ng, 2000), beliefs, etc.

In this study we focus on two specific characteristics that according to earlier research can clearly be linked to the learning outcomes studied in this context: the cognitive style of the pupils and their gender. As to cognitive style, the conceptual framework is adopted of Witkin *et al.* (1977). They distinguish between a *field dependent* and a *field independent* cognitive style. For our research the field independent /dependent cognitive control is useful since it is related to analytical reasoning, formal operational reasoning, and mathematics (Jonassen & Grabowski, 1993).

Recently, Suomala & Alajaaski (2002) found that gender accounted for differences in complex problem-solving processes when a Lego Mindstorms® environment was used. In this study girls demonstrated more cognitive conflict solution processes, more cooperation with teachers and more explicit planning. On the other hand Wang & Ming-Zhang (2003) found that pupils' cognitive style was a significant factor in the demonstration of problem-solving skills among boys but not between girls.

Teacher adoption of constructivist teaching/instructional principles

A clear impact of an ICT-based instructional intervention can only be expected if the use of Logo as a *mindtool* goes along with the clear adoption of specific instructional strategies by the teachers (Swan, 1991). Paying attention to the teaching processes is in line with recent plea of Lesgold (2000) to consider the interaction effect of the teaching variable in researching the impact of educational technology. Also Kulik (2003) stressed this in a recent overview of educational technology evaluation studies since 1990. Studies tend to find more significant changes when teachers are better prepared. The efficacy of the Logo-environment depends on the extent to which teachers address student needs in these environments, ask higher-order questions, provide feedback to problem solutions of students' efforts to solve problems, promote interaction between peers and between teacher and pupils, discuss errors and misconceptions (Clements et al., 1992; Yelland, 2002). Teachers also have to understand the cognitive development of their pupils to foster this development through effective teaching practices (Daniels & Shumow, 2003).

Possible variations in the impact of Logo-use on learning can therefore be due to variations in levels of adoption of social-constructivist instructional principles. In the past, research has hardly controlled for levels of adoption of teaching strategies in

studying the impact of ICT and/or Logo. In this study this variable will be controlled as pupils' perceptions.

Research design

Research questions

The following sub questions are derived from the main research question: (a) What is the impact of the Logo-based instructional intervention on mathematics learning outcomes? (b) What is the impact of pupils' individual characteristics on their mathematics learning outcomes? (c) What is the impact of the teachers' teaching principles on the pupils' mathematics learning outcomes? (d) What is the relationship between the levels of cognitive processing demonstrated by pupils and their mathematics learning outcomes? and (e) What is the impact over time of this ICT intervention program on the pupils' mathematics learning outcomes?

In view of answering these questions, the following hypotheses are tested:

1. IEPSE-pupils attain higher mathematics scores compared to pupils that did not participate in the experimental program.
2. Pupils' characteristics (cognitive styles and gender) interact with their mathematics scores.
3. There is a positive relation between the average perception of a teacher by his/her pupils about the adoption of social-constructivist teaching principles and the mathematics scores of his/her pupils.
4. There is a positive relation between pupils' mean levels of cognitive processing and their mathematics scores.
5. IEPSE-pupils attain in 2003 higher mathematics scores as compared to their scores in 2002 and as compared to scores of pupils in the control condition.

Research approach

A quasi-experimental design was implemented with a random assignment of school classes and their teachers to two experimental and one control condition. In view of the

research questions a mathematics test, a cognitive style test, a non-participant observation instrument, and questionnaires were chosen.

Research Sample

Eight fifth-grade classes and their teachers were involved in the study: 3 IEPSE-classes whose teachers had been enrolled in the IEPSE-training (experimental condition A), 3 classes from IEPSE-schools whose teachers had not participated personally in the IEPSE- teacher training (experimental condition B) and 2 classes that were not in the IEPSE-project and whose teachers did not receive training (control condition). Classes in the study were selected on the base of their teachers being/or not being in the project or having received training. All teachers participating in the study work in rural schools of the Peninsula region; they are 45 years-old in average; they have a diploma in primary education; they did not follow post-graduate studies; they did not have previous experience with ICT; and only two of them are female. These teachers' characteristics are comparable to the average coastal region teacher in the Santa Elena Peninsula and from the Guayas province in Ecuador (For details see Chiluiza-García & Valcke, 2004b; Mera & Zurita, 2002).

A stepped sampling procedure was followed to select the eight teachers. At a first stage, 43 schools were selected randomly from the total number of public schools in the Peninsula region (*N*=129). Due to resource constraints, 20 schools were selected from this sample to be involved in the IEPSE-project. This selection was based on the extent to which schools were able to invest time in the project and whether teachers were able to follow the training linked to the project. From the 20 schools included in the IEPSE-project, 6 fifth-grade teachers of six different schools were selected ad random (using code assignment) to be involved in this study. Three fifth-grade teachers were selected ad random from the 23 schools that were – yet - not included in the IEPSE-project. Only 2 teachers answered positively to the request. A further selection and invitation -to get a group of 3 teachers in control group- did not yield positive results; thus control group only consist of two teachers and their classes.

Pupils in the study attend rural public schools, which are not advantaged in terms of teacher number or infrastructure; moreover, the villages where these schools are located are very similar as to demographic indexes such as: illiteracy (11%), poverty

(78%), primary school completion (64.7%), secondary school completion (12%), and so forth (COSASE, 2002).

The total number of pupils in the 8 classrooms participating in this study was 249. Due to pupils being ill, absent, moving to another school, the total number of pupils of which information was available for the complete research period was 202 (focus on Mathematics test) and 204 (focus on perceptions about teaching principles). In the mathematics sample, 41% of them were female and 59% male (similar proportions were observed in the sample of 204 pupils). Sample sizes were consequently different in the three conditions: experimental group A = 91, experimental group B = 83, control group = 28. As to the video analysis of the collaborative work of the pupils, a sub sample of 2 x 4 pupils was randomly selected from the group of pupils in each class. This is explained in more detail in the research procedure section.

The experimental treatment in the IEPSE-project

The sessions for the pupils in the experimental condition A and B, started in August 2000 as extra-curricular activities, with a focus on ICT literacy topics. At this stage of the project none of the pupils were acquainted with computers or keyboard use. In the next stage, from April 2001 until January 2002, IEPSE pupils attended classes where collaborative activities were organized based on Mindstorms® and Logo Microworlds®. In the next school year, starting April 2002, pupils continued with their activities. In the school year starting April 2003, pupils continued this training during regular school hours.

Sixteen to twenty pupils attended the Logo-sessions at the same time in the computer labs. These labs were organized on a two-weekly base. During a school year, pupils worked for about 20 hours with the computers. The teachers, supporting the sessions, were regular school teachers who on average worked 10 hours a week in the ICT-laboratory. For the purpose of this study we focus on the learning activities during the school years 2002 and 2003 and the learning activities of a sample of 5th grade classes (age M =10 in 2002). The activities of these pupils in the project were based on the *mindtools* and implied e.g., planning, programming, testing procedures, use of buttons, influencing turtle behavior, debugging programs, and making presentations of their projects to other peer groups, the school and local educational authorities. Pupils worked in dyads to develop the Logo-projects. The teacher put forward the general

theme of the project, but pupils were completely free to elaborate the projects in their own way. Most project themes built on topics discussed in the normal classroom. Typical themes were related to natural sciences, social sciences, language and mathematics.

Research variables and research instruments

Mathematics learning outcomes

The released version of the TIMSS mathematics test (Mullis et al., 1997) was applied to determine pre-test and post-test mastery of mathematical knowledge and cognitive skills. Reported KR-20 reliability ranges from .82 to .84. This instrument was chosen because no alternative measurement instrument was available in the Ecuadorian setting with verified psychometric qualities. The APRENDO tests, referred to earlier, were not publicly available. The test covers 5 mathematics subscales: (a) fractions and proportionality; (b) geometry; (c) metrics, estimations and sense of numbers; (d) integer numbers; (e) patterns, functions and relationships. The cognitive skills dimension included the following 5 subscales: (a) knowledge, (b) use of routine procedures, (c) problem solving, (d) use of complex procedures, and (e) probabilities. Category e was not included in the analysis because probabilities are not covered at primary school level in Ecuador. The total TIMSS test consists of 65 items.

Pupils characteristic: cognitive style

Pupils' cognitive styles were determined with the Group Embedded Figures Test - GEFT (Witkin, Oltman, Raskin, & Karp, 1971). The GEFT helps to distinguish between field-dependent and field-independent cognitive styles. The reported Spearman-Brown coefficient for this instrument is $\alpha = .82$. In the present study the reliability score was $\alpha = .90$.

Pupils' perception about the adoption of social-constructivist instructional strategies by their teachers

Pupils were asked to fill out the Constructivist Learning Environment Survey – CLES (Taylor, Fraser, & Fisher, 1997). The information drawn from the CLES is helpful to determine pupils' perception of the adoption level of social-constructivist instructional principles by their teachers in sciences classes. The 25 items represent five subscales: personal relevance (PR), uncertainty (UN), shared control (SC), critical voice (CV), and student negotiation (SN). PR refers to the perceived relevance of what pupils learn at school and how teachers build on out of school experiences. UN checks whether opportunities are given for pupils to base knowledge on personal experiences knowledge. SC reflects the extent to which pupils and teachers share control of the learning environment. CV reflects whether pupils are allowed to question the approach and methods of their teacher, and to express their concerns about the learning process. SN assesses whether pupils get opportunities to explain and justify their ideas to others. The reported α for the CLES is between .90 and .85 (Lee & Fraser, 2001; Puacharearn & Fisher, 2004). Pupils filled out the CLES in year 2003; with α =.73. The CLES was also administered in 2002, but the data were incomplete and therefore not considered as useful for this study.

Levels of cognitive processing

Information about the levels of cognitive processing was gathered through observation and analysis of video recordings of group work at the end of the school year 2002 and at the end of the school year 2003. The analysis was based on the content-analysis model of Guanwardena, Lowe & Anderson (1997). They developed the model in the context of studying knowledge construction in computer-supported collaborative learning environments. Five phases or levels of co-construction of knowledge are identified:

level 1: sharing/comparing ideas (observation, agreement, corroboration clarification and definition);

level 2: inconsistency/dissonance about ideas (identifying and stating, asking and clarifying, restating and supporting);

level 3: negotiating what is to finally agreed upon/co-construction of knowledge (proposing new co-constructions that comprehend the negotiated resolution of differences);

level 4: testing tentative constructions (the new constructed statements of ideas are tested, and matched again to personal understandings and other resources);

level 5: statement/application of newly constructed knowledge (final revision and sharing again of the new ideas that have been constructed by the group).

The video recordings were analyzed by a group of three independent researchers. They received a training to work with the model of Gunawardena et al., (1997) in order to reach high interrater reliability. Each video recording was analyzed in time-frames of 2 minutes. The highest level of cognitive processing observed in each pupil in each time frame was coded. All recordings were observed and analyzed simultaneously by the researchers. At the end of each session, the coding was compared and its quality was assessed by determining *Cronbach α*. A value of 0.7 was put forward as a criterion for interrater reliability. The α values for the different discussions varied from .82 to .99 for year 2002 and from .79 to .98 for year 2003. To control for systematic differences in coding, the coding session was extended with a discussion about the differences in coding. This procedure has been found to be useful to assure consistency (Stemler, 2004). This procedure could or could not result in some minor changes in coding by a coder. After this discussion phase interrater reliability was recalculated (between .91 and .99 for both years). To check whether it was not always the same researcher changing the coding category, *Cronbach α* was also calculated for each individual researcher. This coefficient was calculated between the first and final coding of a unit of analysis. The α coefficient was always between .75 and .99 in both years.

The GEFT, TIMSS and CLES were translated from the English-language version into Spanish, using the translation and back-translation method of Behling & Law (2000). The Spanish versions were pilot tested using a small sample of pupils to ensure their clarity and legibility. These pupils did not participate in the further study.

Procedure

The study initiated in April 2002, one year after the initial start of the IEPSE-project with mindtools and lasted for two school years. At the start, the GEFT and the CLES were administered from all pupils. At more general level information about age, gender and background information was gathered from the pupils. After this pre-testing phase, the pupils in the experimental conditions continued working with the Logo-mindtools.

At the end of the school year 2002, the TIMSS test was administered from the eight classes of the study. In addition, 2 groups of 4 pupils (2 girls/2 boys) were selected at random from each of the eight classes. These groups were asked to carry out a collaborative problem-solving task. The group task was based on task specifications of Joyce, Calhoun & Hopkins (2002). In this task, each group had to plan a trip or a reunion, based on role-play. Pupils decided which role was best to reach the goals. The task incorporated rules, a minimum budget, constraints about places to visit, places to buy necessary items, and it included a clear documentation of the steps the pupils had to follow for reaching the goal, next to a clear description of the final task requirements. The collaborative work of each of the 16 teams was video taped. The session lasted about one hour.

The same procedure was followed at the end of the school year 2003. The same eight teams were asked to carry out a collaborative group task. Pupils who participated in the 2002 study and were not enrolled in school year 2003, were replaced by – ad random selected - other pupils. Again the group work was video taped. Also the TIMSS was presented to all pupils in the three research conditions. It is to be stressed that at the end of 2003, the research was negatively influenced by a long national strike in Ecuador. An obvious attempt was made to guarantee a regular continuation of the research procedure, but this could not prevent that the overall school atmosphere was affected in a negative way.

Statistical analysis

Statistical analysis is based initially on descriptive statistics. ANOVA and MANOVA were used to study the impact on mathematics scores. ANOVA (repeated measures - between subject factors) was applied to test the impact over time. A linear regression analysis was used to find a relationship between mathematics scores and average perception of teachers by their pupils about the adoption of social-constructivist

teaching principles. In addition, a logistic regression was used to test hypothesis 4 instead of linear regression. Assumptions for linear regression were not met for this study e.g. large number of observations, and equal variance distributions of the dependent variable for each different value of the independent variable –mean level of cognitive processing. We therefore opted for logistic regression and levels of mathematics scores (low to medium/high) were used as the dependent variable.

Descriptive results

Table 1 gives a summary of the TIMSS scores in year 2002 and 2003. We perceive overall higher total scores in years 2002 and 2003. Pupils in the experimental conditions demonstrate relatively higher scores. But the results also show how low the mastery of mathematics knowledge is in this sample. This is consistent with the findings of the APRENDO tests reported earlier. Pupils were categorized according to their mathematics scores in two categories: low to medium (25th to 75th percentiles) and high ($>75^{th}$ percentile).

Pupils were categorized according to their cognitive style in three categories: field dependent (FD = 31%), field dependent/independent (FDI = 33 %) and field-independent (FI = 36%). Table 2 summarizes the results of the CLES-test, administered in 2003. Table 3 summarizes the distribution of the proportions of different levels of cognitive processing as observed in the pupil interactions at the end of both school years. Interestingly, only pupils in the experimental conditions had participations in all levels. Mean levels of cognitive processing for each pupil was used to test hypothesis 4.

Table 1. TIMSS Scores and subscores for 2002 (*N*= 239) and 2003 (*N*=249)

	Variables	Experimental A (*n*=105)				Experimental B (*n*=98)				Control Group (*n*=36)			
		Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Year 2002	TIMSS – total score	0	37	14.9	6.9	1	42	18.0	7.7	0	30	11.7	6.9
	Knowledge	0	14	5.4	2.9	1	15	6.4	2.7	0	12	3.9	2.9
	Routine procedures	0	7	2.6	1.3	0	7	2.7	1.5	0	6	2.7	1.5
	Problem solving	0	13	4.1	2.8	0	14	5.0	2.8	0	11	2.8	2.5
	Complex procedures	0	9	3.4	1.9	0	11	4.7	2.8	0	7	2.9	1.9
	Fract. & Prop.	0	7	2.3	1.7	0	9	2.9	1.9	0	4	1.5	1.2
	Geometry	0	9	3.5	1.7	0	9	3.9	1.9	0	4	2.3	1.4
	Metrix	0	8	2.2	1.6	0	6	2.6	1.4	0	5	1.5	1.5
	Integer numbers	0	10	4.1	2.1	0	14	4.5	2.7	0	16	4.2	3.2
	Patterns and functions	0	7	2.0	1.6	0	7	2.7	1.5	0	7	1.8	1.7
		(*n*=113)				(*n*=104)				(*n*=32)			
Year 2003	TIMSS – total score	4	51	20.4	8.7	3	57	20.5	10.9	0	42	19.6	8.4
	Knowledge	4	16	6.3	3.2	3	19	7.3	3.9	0	13	7.3	2.8
	Routine procedures	0	7	2.9	1.5	0	7	3.1	1.8	0	7	2.9	1.6
	Problem solving	0	14	5.1	3.3	0	16	4.7	3.8	0	10	4.3	2.6
	Complex procedures	0	13	4.7	2.7	0	14	4.7	2.8	0	13	3.9	3.0
	Fract. & Prop.	0	12	4.3	2.6	0	12	3.9	2.7	0	10	3.7	2.3
	Geometry	0	8	2.6	1.8	0	10	3.4	2.2	0	8	2.9	1.8
	Metrix	0	9	2.9	1.9	0	9	2.8	2.0	0	6	3.1	1.5
	Integer numbers	0	14	5.5	2.7	0	15	6.3	3.4	0	16	5.5	3.2
	Patterns and functions	0	8	3.1	1.7	0	8	2.8	2.0	0	7	2.8	1.7

Table 2. Descriptive statistics of the total CLES score and the CLES dimensions (*N*=204)

Groups	Experimental A (*n*=86)		Experimental B (*n*=89)		Control Group (*n*=29)	
Scales	*M*	*S.D.*	*M*	*S.D.*	*M*	*S.D.*
Total Score	93.40	8.80	86.35	9.64	83.17	8.29
Personal relevance	20.42	1.97	20.40	2.55	18.17	3.05
Uncertainty	19.93	2.31	20.83	2.37	17.00	2.99
Critical voice	17.65	3.24	14.45	3.65	16.41	2.47
Shared control	16.30	3.79	13.33	4.02	14.52	2.53
Student negotiation	19.12	2.35	17.33	3.42	17.07	2.89

Table 3. Distribution of proportions of levels of cognitive processing in collaborative tasks based on Gunawardena et al. (1997) for 2002 (*N*=870 participations) and 2003 (*N*=1147 participations)

	Group	Phases in cognitive processing %				
		Level 1	Level 2	Level 3	Level 4	Level 5
Year 2002	Experimental A	74.3	2.0	17.3	6.5	-
	Experimental B	66.5	-	23.2	9.7	0.6
	Control	83.4	-	11.7	4.9	-
	Total	73.6	0.7	18.2	7.4	0.2
Year 2003	Experimental A	97.4	0.9	1.3	0.2	0.7
	Experimental B	94.7	1.3	3.8	-	0.3
	Control	100.0	-	-	-	-
	Total	97.1	0.8	1.7	0.1	0.3

Results

Hypothesis 1: IEPSE- Pupils attain higher mathematics scores compared to pupils that did not participate in the experimental program.

Univariate ANOVA was used to test differences in TIMSS total scores of the pupils in the three conditions in year 2002. This is one year after the start of the program with the use of the mindtools. A significant effect is observed. IEPSE pupils demonstrate significantly higher mathematics scores $F(2,234) = 10.885$ ($p<0.001$, *partial* $\eta^2 = .09$, where .01, .06, .14 indicate small, medium, or large effect sizes; Cohen, 1988). Post hoc analysis was performed. Multiple comparison analysis (Scheffe-test) resulted in

meaningful differences between experimental condition A and the control group ($p < .1$) and significant differences between experimental condition B and the control group ($p < .001$) and experimental condition A ($p < 0.05$).

MANOVA was run, with the four cognitive skills subscales of TIMSS (knowledge, routine procedures, problem solving and complex procedures) as the dependent variables and conditions as the independent variable. Pillai's trace statistic was used to analyze the differences. Pillai's statistic value (.79) was significant $F(8, 468) = 5.46$ $p < .001$, *partial* $\eta^2 = .09$. Univariate analysis (ANOVA) for each dependent variable reflects significant differences between conditions for each dependent variable: knowledge, $F(2,236) = 10.87$, $p < .001$, *partial* $\eta^2 = .08$; problem solving, $F(2,236) = 8.46$, $p < .001$, *partial* $\eta^2 = .07$; and complex procedures, $F(2,236) = 11.35$, $p < .001$, *partial* $\eta^2 = .09$. No significant differences were found for the subscale 'routine procedures'. *Post hoc* analysis was performed, taking into account that variances were not homogeneous for the 'complex procedures' subscale. Table 4 summarizes the values of the Scheffe and Tamhane multiple comparison tests.

Table 4. Results of the multiple comparisons (MANOVA) of the cognitive skills subscores of the TIMSS to test hypothesis 1 for 2002

Dependent variable	Differences among means in multiple comparisons
Knowledge[a]	Experimental A – Control (1.60) *
	Experimental B – Control (2.52) **
	Experimental B - A (0.92)
Problem-solving[a]	Experimental A – Control (1.27)
	Experimental B – Control (2.17) **
	Experimental B - A (0.90)
Complex-procedures[b]	Experimental A – Control (0.46)
	Experimental B – Control (1.76) **
	Experimental B - A (1.30)*

[a]Scheffe multiple comparisons. [b]Tamhane multiple comparisons
*$p < .05$
**$p < .001$

MANOVA was also run, for the four mathematics knowledge subscales of the TIMSS as the dependent variables and conditions as the independent variable. Pillai's statistic value (.80) was significant $F(10, 466) = 4.53$ $p < .001$, *partial* $\eta^2 = .09$. Univariate analysis (ANOVA) for each dependent variable reflects significant differences between conditions for each dependent variable: fractions and proportionality, $F(2,236) = 7.95$, $p < .001$, *partial* $\eta^2 = .06$; geometry, $F(2,236) = 12.27$,

$p<.001$, *partial* $\eta^2 = .09$; metrics, estimations and sense of numbers, $F(2,236) = 6.91$, $p<.05$, *partial* $\eta^2 = .06$; patterns, functions and relationships, $F(2,236) = 6.44$, $p<.05$, *partial* $\eta^2 = .05$. No significant difference was found for the integer numbers subscale. *Post hoc* analysis was performed, table 5 summarizes the values of the Scheffe multiple comparisons.

Table 5. Results of the multiple comparisons of mathematics sub-scores of the TIMSS to test hypothesis 1 for 2002

Dependent variable	Differences among means in Scheffe multiple comparisons
Fractions and proportionality	Experimental A – Control (0.80)
	Experimental B – Control (1.33) *
	Experimental B - A (0.53)
Geometry	Experimental A – Control (1.23) *
	Experimental B – Control (1.68) **
	Experimental B - A (0.45)
Metrix, estimations and sense of numbers	Experimental A – Control (0.66)
	Experimental B – Control (1.06) *
	Experimental B - A (0.40)
Patterns, functions and relationships	Experimental A – Control (0.24)
	Experimental B – Control (0.92) *
	Experimental B - A (0.67)*

*$p<.05$
**$p<.001$

Up to this point, it can be concluded that there are significant differences in year 2002 between the pupils in the experimental B and the control group, but marginal or no differences between pupils in the experimental condition A and the control group.

The same procedure was repeated on the TIMSS scores of 2003. No overall significant difference in TIMSS-scores was observed $F(2,246) = 0.111$, $p>.05$, *partial* $\eta^2 = .001$. A MANOVA was run, with the five cognitive subscales of the TIMSS as the dependent variables. The Pillai's statistic value (.08) was significant $F(8, 488) = 2.63$ $p<.05$, *partial* $\eta^2 = .04$, but univariate analysis for each dependent variable did not reflect significant differences between conditions.

MANOVA was also run, with the five mathematics subscales of the TIMSS as the dependent variables. Pillai's statistic value (.14) was significant $F(10, 486) = 3.67$ $p< .001$, *partial* $\eta^2 = .07$. Univariate analysis for each dependent variable reflects only significant differences between conditions in relation to the geometry subscale $F(2,246)$

= 4.64, *p<.05, partial* η^2 = .04. *Post hoc* analysis shows a significant difference between the means of experimental condition B and A (0.81, p=.011).

Regarding this part of the analysis, it can be concluded that there are significant differences between the pupils in experimental condition B and A in year 2003.

Overall, it was found that pupils in the experimental conditions reached higher mathematics scores in both years, though the differences are not significant for all the TIMSS sub-scales. Remarkable differences were found between pupils in experimental condition B and pupils in the other two conditions in 2002. However, the differences are less pronounced in 2003, and the significant differences are only visible for the geometry subscale among experimental condition A and B. The null hypothesis cannot be rejected. Testing hypothesis 5 will help to get a clearer picture as to the question whether the differences in 2003 are still significant when we take into account the significant differences in 2002.

Hypothesis 2: Pupils' characteristics (cognitive styles and gender) interact with their mathematics scores.

To test this hypothesis in relation to the impact of cognitive style and gender in year 2002, a 2-way ANOVA was applied, using three group conditions in the cognitive style: FD, FDI, FI and gender differences as independent variables. No main effect of the gender of the pupils and their mathematics scores was found F (1,210) = 3.54 *p* > .061, *partial* η^2 =.02. There was a significant main effect of cognitive style on mathematics scores, F (2,210) = 14.73 *p* < .001, *partial* η^2 =.12. *Post hoc* analysis was performed Scheffe multiple comparisons yielded significant differences among the FI – FD conditions (difference in means = 6.84, *p<.001*) and among the FI-FDI conditions (difference in means = 3.52, *p<.05*). There was no significant interaction between the cognitive style and gender, F (2,210) = 0.098, p <.906, *partial* η^2 =.001.

For year 2003 the same analysis (2-way ANOVA) was repeated. No main effect of the gender of the pupils and their mathematics scores was found F (1,190) = 2.36 *p* > .127, *partial* η^2 =.01.   There was a significant main effect of cognitive style on mathematics scores, F (2,190) = 13.77 *p* < .001, *partial* η^2 =.13. *Post hoc* analysis was performed, it was found that the variances were not homogeneous (Levenes' test). Tamhane multiple comparisons yielded significant differences among the FI – FD

conditions (difference in means = 9.03, $p<.001$) and among the FI-FDI conditions (difference in means = 4.53, $p<.05$). There was no significant interaction between the cognitive style and gender, F (2,190) = 0.01, p >.1, *partial η^2 =.000*.

In summary, we can conclude that FI pupils reached higher scores than FD pupils on the TIMSS test in both years. Pupils' gender did not significantly affect the mathematics scores. There is no interaction between gender and cognitive styles. Based on these results the null hypothesis is rejected.

Hypothesis 3: There is a positive relation between the average perception of a teacher by his/her pupils about the adoption of social-constructivist teaching principles and the mathematics scores of his/her pupils.

A linear regression analysis was performed with mathematics scores as the dependent variable and average perception of teachers by their pupils about the adoption of social-constructivist teaching principles (CLES-ratings pupils' version) as the independent variable. Using the enter method, a non-significant model emerged F (1, 190) = .31, p = .578, adjusted R^2 = .04. Based on these results the null hypothesis cannot be rejected.

Hypothesis 4:   There is a positive relation between pupils' mean levels of cognitive processing and their mathematics scores.

A logistic regression analysis was performed with level of mathematics scores (low to medium/high) as the dependent variable and mean level of cognitive processing of pupils as the predictor variable. A total of 62 cases for year 2002 were analyzed and the full model was significantly reliable in the omnibus test (χ^2 (1) = 4.71, p=.03). On one hand, this model accounted for 7.3% to 10.1% of the variance, with 92.7% of pupils in the low to medium category of mathematics score successfully predicted. On the other hand, only 33.3% of predictions for the high category of mathematics score were accurate. Overall 72.6% of predictions were accurate. The values of the Wald statistic for the predictor variable is significant; 4.51 (p=.034). The estimated logit is Log [p/(1-p)] = -2 + 0.89*mean level of cognitive processing in year 2002. The coefficients (B= 0.89 and Exp(B) = 2.44) show that each unit increase in the mean level of cognitive processing is associated with an increase in the odds of falling in category high of mathematics score by a factor of 2.44. The same procedure was used with the data from

2003 (N= 63). Again, the model resulted significantly reliable in the omnibus test (χ^2 (1) = 9.38, p=.002). The model accounted for 13.8% to 18.5% of the variance, with 88.6% of pupils in the low to medium category of mathematics scores successfully predicted. However, only 35.7% of pupils from the high category of mathematics scores were accurately predicted. In general, 65.1% of predictions were accurate. The values of the Wald statistic for the predictor variable is significant; 5.50 (p=.019). The estimated logit is Log [p/(1-p)] = -11.29 + 10.68*mean level of cognitive processing in year 2003. The coefficients (B= 10.68 and Exp(B) = 43,349.52) show that each unit increase in the mean level of cognitive processing is associated with an increase in the odds of falling in category high of mathematics score by a factor of 43,349.52.

Both models are significant and they describe a positive relation between the variables studied; though, the sample size is limited. Based on these results we can reject the null hypothesis.

Hypothesis 5: IEPSE-Pupils attain in 2003 higher mathematics scores as compared to their scores in 2002 and as compared to scores of pupils in the control condition.

Repeated measures (GLM) was used to test hypothesis 5 with as within-variables the TIMSS scores for 2002 and 2003 and as between-subject factors the three conditions. As was clear after testing hypothesis 1, there were significant differences in mathematics scores obtained by pupils in both year 2002 and 2003 F(1, 199) = 112.12, p<.001, *partial η^2* = .36. Meaningful differences were found in scores obtained by pupils under the three conditions over time, F (2, 199) = 2.83, p<.1, *partial η^2* = .03. Figure 1 depicts the means for year 2002 and 2003 for the students in the three conditions. Overall IEPSE pupils reached higher mathematics scores than pupils from the control condition; however, based on these results the null hypothesis cannot be rejected.
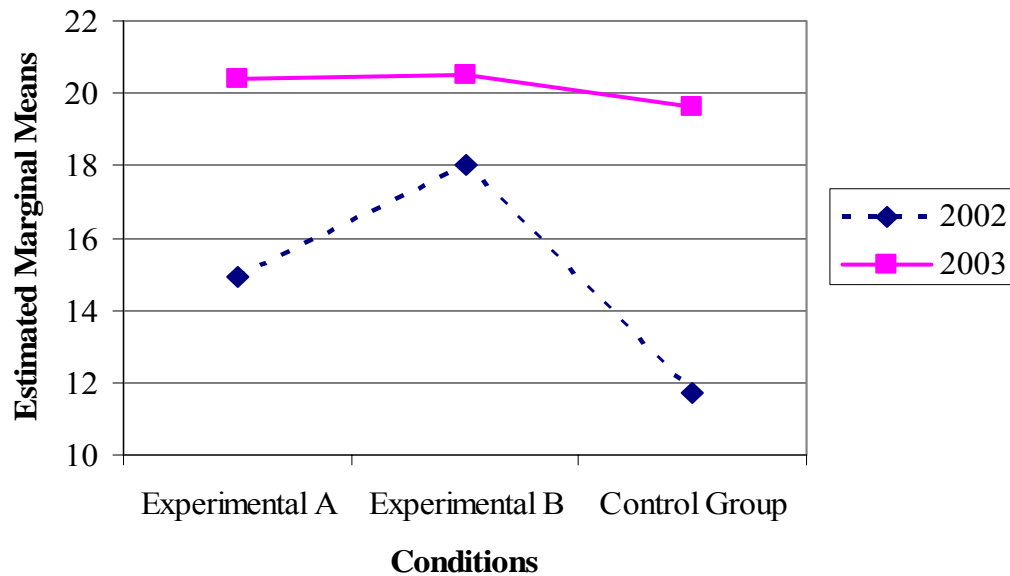
Figure 1. Estimated marginal means for TIMSS in 2002 and 2003.

Discussion

The aim of this study was to answer the following question: What is the impact over time of the IEPSE project – the use of the Logo-mindtools and the changes in teaching strategies - on the mathematics learning outcomes of 5th grade pupils? In view of answering this general research question, five different hypotheses were tested. In the next paragraphs, the discussion will be structured along these hypotheses.

Already in 2002, one year after the start of the mindtools activities in the project, IEPSE pupils attained higher mathematics scores than pupils in the control condition. Pupils in experimental condition A and B performed better for the subscales: knowledge and geometry. Pupils in experimental group B –whose teachers were linked to the innovation project, but were not trained by the project- attained higher scores in the subscales problem-solving, complex procedures, fractions and proportionalities, metrix, and patterns and functions when compared to pupils in the control condition. Surprisingly, in contrast to our expectations this last set of differences was not found between pupils in experimental group A, and control group. Moreover, we found differences between experimental groups B and A in the complex procedure, and patterns and functions TIMSS subscales. Thus, we have to conclude that pupils from condition B are different from those in the two other conditions. This difference in the

groups might be explained by the sampling approach. The classes were selected on the base of their teachers being linked to the IEPSE project or having attended to the IEPSE training. The authentic setting of this study leaves open room for less controlled variation at classroom and pupil levels. Nonetheless we tried to assure that pupils in the study have similar demographical characteristics (through randomized selection of teachers and classes) e.g., they attend to rural schools; they come from small rural villages. But, there is some variation between rural villages and rural villages that are closer to towns. We think that pupils –in experimental condition B- could have been influenced and/or stimulated in a richer way than those who live in rural villages –not near to more developed towns. A second explanation might be related to differences in prior knowledge. Overall the positive results from experimental group B coincide with the findings of other researchers, when exposing children to Logo-based activities (Au & Leung, 1992; Swan, 1991; Clements et al., 1992). Interpretation of these results is marred by the fact that no data are available about the earlier mathematics performance of the pupils in the three conditions. The APRENDO tests of the year 2000 suggest that the overall mastery of mathematics is weak, but it was not possible to check for already existing differences between the pupils in the different samples prior to 2002.

In 2003 no significant differences were found in the total TIMSS scores between the pupils in the research conditions. An analysis at the level of the TIMSS subscales revealed only significant differences for the geometry subscale between pupils in experimental condition A and B but not in the control condition. The expected impact on this specific mathematics subscale is in line with earlier scientific evidence that points at the direct relevance of the Logo-instructions to develop spatial concepts and general geometry knowledge (Clements, 2002; Clements et al., 1992). It is difficult to explain the fact that in 2003 no longer significant differences have been detected between the experimental and control groups. Analysis of the nature of the collaborative activities, building on the Logo-mindtools, can also offer a clarification for the lack of impact. We expect the Logo-based activities to influence the acquisition of mathematics knowledge, but the activities covered a wide variety of subject-related problems. Of course, due to the nature of the Logo-tools, solution of the problems and the graphical representation always implied the application of mathematical knowledge and procedures. But the core of the problem was in many cases only indirectly related to mathematics. This lack of focus in mathematics in the collaborative task questions the transfer potential of the learning tasks and problems dealt with.

Regarding the impact of specific characteristics of the pupils, it was found that pupils with a field independent cognitive style reached significantly higher TIMSS scores; both in year 2002 and 2003. These findings are in line with findings of other researchers (Jonassen et al., 1993). As to gender, boys scored higher than girls in both year; yet not significantly. Some researchers found that differences in mathematics scores are related to gender and some did not find differences. But there is a consistent trend in the research to observe lower gender differences than reported in earlier research (Brusselmans-Dehairs & Henry, 1994; Mullis et al., 1997; Mullis et al., 2000).

Perceptions of the pupils about the adoption of social-constructivist teaching strategies by their teachers were not related to their mathematics scores. Other researchers did find positive relationships between the teacher's teaching principles and the learning outcomes (Clements, 1999; Sarama & Clements, 2004) and the importance of the role of the teacher as a creator of intellectual stimulating environments and tasks (De Corte, 2000). A possible explanation for these inconsistent results might be related to the fact that the pupils were asked to rate the teaching behavior of their teachers in science classes. The kind of teaching in these classes can still be different from the approach intended by the IEPSE-project; e.g., due to the use of very structured science-manuals, or the difficulty teachers find in putting theory into practice (Korthagen & Kessels, 1999). Another weakness might be related to the fact that we judged the adoption of social-constructivist teaching by building on perceptions of the pupils. These perceptions could have been compared to other measures of the same construct, e.g., based on structured interviews or a forum discussion (Lee et al., 2001), or actual teachers' behaviors in the classroom.

The average/mean levels of cognitive processing of pupils are positively related to the attainment of higher mathematics scores. This relationship was found in both year 2002 and 2003. These results replicate the findings of Mullis et al.,(2000) who researched mathematics outcomes at an international level. They found that pupils who attended classes where there was a strong emphasis on reasoning and problem-solving, obtained significantly higher scores on the TIMSS test. In addition, Gauvain (1998) summarizes research findings that could link the collaborative context to a positive cognitive development in mathematics attainment. In the literature, few studies have been found that focus on this specific hypothesis and/or corroborate or contradict the present results. As a weakness we have to state that the sample sizes for both years were rather small. Sample sizes have affected the statistical analyses used in the study and

have obliged the researchers to opt for methods –logistic regression and consequently the use of categorical variables- that lower the power of these analyses. In favor, however, a trend is also observed in both set of data, and the results were significant for 2002 and 2003.

The null hypothesis about the impact over time of the IEPSE project on mathematics scores could not be rejected. Even though the mathematics scores were higher in 2003 as compared to 2002, the differences were not significant when we take into account the pre-existing differences in 2002. Other researchers have reported a positive long term impact of logo-based education software on pupils outcomes (Chang, 1989; De Corte, 1993). As suggested earlier, the transfer value of Logo-based learning activities to learn mathematics can be questioned. This was also suggested in the research of Kynigos (1989). He concluded that learning strategies acquired in Logo-based environments were not easily transferred to other environments. Based on Verschaffel et al., (1990) we can also criticize the duration of the IEPSE experimental treatment in view of expecting an apparent impact on mathematics scores and or transfer of what was learned to the mathematics knowledge domain. Verschaffel et al. could only report a significant change in thinking skills and/or mathematics performance after exposing pupils to 60 hours of Logo during one school year. But, as put forward, the lack of direct focus on mathematics related tasks when using the *mindtools* is another weakness that might have impacted negatively on the results obtained in the study.

In retrospect, we can point at the following strengths of the present study. It was set up in an authentic setting, involving normal classes. The impact was measured by presenting fair tests (TIMSS) or measurement conditions (observation of a non-Logo related collaborative task). The time pupils practiced with the Logo-mindtools was about 60 hours, spread over 3 years. However, the frequency of the Logo-activities was rather low. The frequency was also influenced by a long strike of the teachers in the 2003 Ecuadorian setting. We think that this factor had a negative influence on the overall learning outcomes and might help to explain the specific mathematics scores for all the conditions in 2003.

The number of variables and processes measured and controlled for in this study was large. But again given the quasi-experimental nature and the naturalistic setting of the study, this number is still limited to be able to control for all variables that might affect pupil behavior. As stated earlier, also other variables internal and external to

pupils are known to have a large impact on their learning process. Critical issues not considered in this study are e.g. the school environment, pupils' belief, participation and educational level of the parents, ICT-skills of the pupils, etc. The sample size to test hypotheses related to the impact of cognitive processing was also a constraint for the study. The inclusion of a bigger sample is suggested in future studies.

Future research should consider a more intensive experimental treatment, a better control of mastery levels of all dependent variables at the start of the study, and the administration of near and far transfer tests. Next to the impact on mathematics tests, also the impact on the acquisition of other knowledge domains that are reflected in the collaborative Logo-tasks could be studied. As to the levels of adoption of social-constructivist teaching principles, pupil perceptions could be enriched with e.g., observation and qualification of the actual instructional strategies of the teachers.

Conclusions

What has been the impact of the IEPSE project – the use of the Logo-mindtools and the changes in teaching strategies - on the mathematics learning outcomes of 5th grade pupils? It can be concluded that the impact on the mathematics learning of IEPSE-pupils was only marginally positive or not positive. Mathematics scores were related to the levels of cognitive processing demonstrated in collaborative problem-solving tasks. Consistent findings about the relationship between cognitive style and mathematics performance were presented. The results were also clear about the impact of gender and consistent with current research. More research is needed to be able to generalize the present findings. Future research should pay closer attention to pupil characteristics, pre-testing, the nature and knowledge domain of the transfer tests, the duration of the experimental treatment and approaches to determine the level of adoption of innovative teaching strategies.

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Chapter 5

Impact of an innovative ICT-based educational programme on the teaching and learning activities of primary schools in the Ecuadorian setting.
A qualitative study[*]

Abstract

A qualitative research design (focus groups, Delphi study and the Metaplan® method) tried to corroborate the findings of quantitative studies about the impact of an innovation project in Ecuadorian schools of the Santa Elena Peninsula region. Teachers were trained to adopt social-constructivist teaching strategies by working with Lego Mindstorms® and Logo Microworlds® as mindtools, in close connection to their teaching in the classroom. The qualitative study corroborated most of the findings about the adequacy of the training approach and content, the high levels of adoption of the new teaching strategies, and the changes in attitudes of pupils and teachers.

Introduction and general research problem

The present study researches the impact of an ICT-based educational program in Ecuador. This research is linked to the evaluation of the innovation of education in the Santa Elena Peninsula project (IEPSE). The project focuses initially on teachers and the adoption of social-constructivist teaching strategies. But, the teachers also started to apply the new competencies in their classrooms. In the IEPSE initiative teachers used Lego Mindstorms® and Logo Microworlds® with their pupils. Previous studies about the IEPSE project reported that: (a) the training offered by the IEPSE for in-service teachers goes in line with current international trends in teacher education, (b) the IEPSE-teachers highly adopt the social-constructivist teaching strategies, and (c) IEPSE pupils demonstrate slightly higher levels of cognitive processing than other pupils that are not enrolled in the program. However, these findings were mainly based on quantitative studies. This brings us to the central research problem for this research

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article. Are the results of the quantitative studies corroborated by adopting qualitative methods?

In this article, we first present a description of the IEPSE-project. Next we discuss a theoretical framework in relation to factors identified as to be related to an effective/improved use of ICT in teaching and learning in schools, before presenting a discussion of the key research variables in the study. After presentation and discussion of the results, directions for future research are given.

The IEPSE project

Background

Ecuador lacks for an updated educational policy, the current educational reform dates from year 1992 and it has not been reviewed since that year. There is no systematic educational evaluation at the national or local level. The only attempt to measure or assess the status of Ecuadorian students in relation to their language and mathematics skills was based on a set of tests applied at the national level to a sample of pupils from second (7 years-old), sixth (11 years-old) and ninth grade (14 years old) of basic education (k-14). These tests were called APRENDO and were applied in 1996, 1997 and 2000. The results obtained in year 2000 confirmed the results from the previous years. The higher the grade, the higher the proportions of pupils categorized in beginner or basic level (64%-75%) and very few in the high or master level (10%-16%). Next to this national evaluation study no evaluation has been set up in relation to teachers, students, schools, curricula, etc. The Ecuadorian State has put some efforts in reducing the digital divide at the teacher level through a large scale teacher training program (10,000 teachers), Maestr@s.com (Teachers.com); which focuses mainly on ICT-literacy training (for more details see: http://www.cti.espol.edu.ec/maestros/index.htm). No further follow-up or continued training to this initiative has been initiated.

Although the results of the APRENDO evaluation are striking, very few or none efforts have been put in innovation and reformation of education or in a teacher training program to enhance their knowledge and skills related to adequate teaching principles. These skills were identified as a central weakness in Ecuadorian teachers (MEC, 2002). The Ecuadorian State has to confront several social, political and economic problems. One example is the consecutive strikes from health, educational, agricultural,

indigenous, and other social groups that hamper the normal development of enhancement and innovation in the country. Another important shortage is the lack of public policies that help to induce such initiatives. Other institutions, such as NGO's and universities have initiated some innovation programs in education. One example is the IEPSE project run by the Escuela Superior Politécnica del Litoral - ESPOL, and Ecuadorian university. In the next section we describe the characteristics of this project.

Characteristics of the IEPSE project

During the last five years, the ESPOL has implemented a pilot project to innovate primary education in Ecuador through the use of ICT. The IEPSE project consists of several components: (a) an in-service teacher training program, (b) deployment of computer labs with internet access in public rural and urban marginal coastal schools, (c) follow-up activities of teachers and pupils, and (d) technical and instructional support for teachers trained in the program. 20 primary schools, 40 teachers and nearly 8,000 pupils from first to sixth grade (6-11 years old) were initially involved in the project. Currently, more than 43 schools are part of the IEPSE-network and the teaching of more than 10,000 pupils is affected.

IEPSE teachers were trained to adopt social-constructivist instructional principles in their classrooms while integrating ICT tools into their teaching. Constructivist learning is characterized by involving learners in situated and authentic activities that mirror the real world (Duffy & Jonassen, 1992). Learning is active (manipulative, observant), constructive (articulative, reflective), intentional (reflective, regulatory), authentic (complex, contextualized, realistic), and cooperative, collaborative, conversational and socially negotiated (Bednar, Cunningham, Duffy, & Perry, 1992; Driscoll, 2000; Jonassen, Howland, Moore, & Marra, 2003; Schunk, 2004). Several methods of instruction that foster conditions for constructivist learning have been suggested e.g., the use of microworlds, problem-based learning, collaborative learning, hypermedia, open-ended learning environments, role plays, etc. (Driscoll, 2000).

The IEPSE training helped to experience hands-on the above principles about learning and instruction. The teachers were also trained to master the didactical strategies that promote constructivist learning. The IEPSE teachers learned to design complex, relevant and contextual tasks that are to be tackled in a collaborative way by

the pupils. These tasks involve the use of mindtools, such as Logo-Microworlds® and Lego Mindstorms®. These tools are considered to be *mindtools*, since they are in line with the definition of Jonassen: (a) the ICT-application can be used to represent knowledge; (b) the experience is generalizable to content in different subjects (in this case mathematics, natural sciences, geography, etc.); (c) it engages learner in critical thinking about the subject; (d) it develops skills transferable to other subjects; (e) it significantly restructures or amplifies thinking (Jonassen, 1996; Jonassen et al., 2003). Teachers attending the training workshops immediately applied the new competencies in their classrooms.

From 2000 on, pupils were offered extra-curricular activities, with a focus on ICT literacy topics. At this stage of the project none of the pupils were acquainted with computers or keyboard use. In the next stage, from April 2001 until January 2002, IEPSE pupils attended classes where collaborative activities were organized based on Mindstorms® and Logo Microworlds®. From the school year 2002 and continuing in 2003, the ICT-based learning activities were organized during regular school hours.

In the IEPSE-project, sixteen to twenty pupils attended the Logo-sessions in the computer labs, working in groups of about three to four pupils. These labs were organized on a two-weekly base to make it possible that complete classes could be involved in the project. During a whole school year, pupils worked for about 20 hours with the computers. For the purpose of this study we focus on the learning activities during the school years 2002 and 2003 and the learning activities of a sample of 5th grade classes (age M =10 in 2002). The activities of these pupils in the project were based on the use of the Logo-*mindtools* and implied e.g., planning, programming, testing procedures, use of buttons, influencing turtle behavior, debugging programs, and making presentations of their projects to other peer groups, the school and local educational authorities. Pupils worked in dyads to develop the Logo-projects. The teacher put forward the general theme of the project, but pupils were completely free to elaborate the projects in their own way. Most project themes built on topics discussed in the normal classroom. Typical themes were related to natural sciences, social sciences, language and mathematics.

The schools participating in the IEPSE-project have a computer laboratory with on average 10 computers connected to a local area network and - where a phone line is available- access to the Internet. Teachers were continuously involved in follow-up activities. These were mainly focused on technical and educational support to teachers.
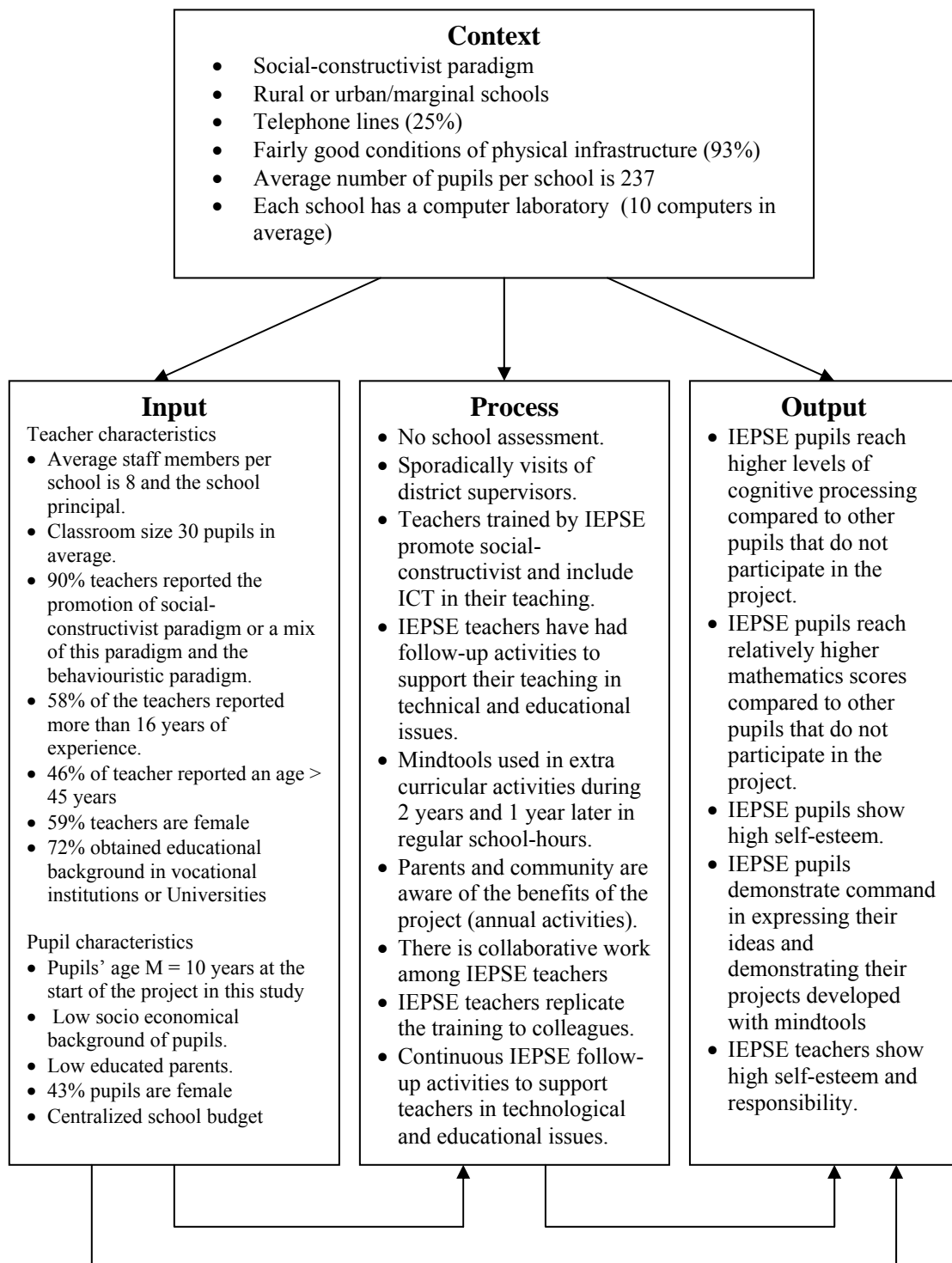
Teachers were videotaped and watched each others work, commented it, and shared experiences. The adoption of social-constructivist teaching strategies was central in these discussions and the use of the Logo- *mindtools.*

<div align="center">Theoretical frame of reference</div>

The IEPSE project was conceived as a way to enhance teaching and learning in primary school in the Peninsula region in Ecuador and thus as a way of schools' improvement. The CIPO-model (Scheerens, 1992) will be used as a guide to describe and explain the impact of the IEPSE project on the participating schools. The CIPO model incorporates the following set of variables: context, input, process and output and has been developed to integrate the findings of a vast body of educational research about schools effectiveness. Figure 1 describes the IEPSE program in terms of this model. Only the most relevant information about the IEPSE program has been included in figure 1, additional information has been reported in previous articles (see for details Chiluiza-García & Valcke, 2004a).

<div align="center">*Context variables*</div>

The national educational policy and school policy has been identified as important factors in the effective use of ICT in schools (Reynolds, Treharne, & Tripp, 2003; Tearle, 2003). The number of students per classrooms and access to equipment is another factor in the integration of technology in the classroom (Smeets & Mooij, 2001). However, in this study we are especially interested in discovering the context in terms of the educational orientation and national / school policy that surround IEPSE teachers and the relevance of the IEPSE program in the Ecuadorian context. The Ecuadorian Ministry of Education (2002) puts forward the following policy guidelines in view of qualitative changes in teachers: the adoption of teaching principles that promote active, critical, and reflective learning with constructive and participative emphasis. Previous research (Chiluiza- García et al., 2004a) could show that the IEPSE-project is in line with international trends in ICT teacher education and also with the aforementioned guidelines. The competencies pursued in the teachers in the Peninsula region reflect social constructivist principles. Other contextual factors and conditions were also reported in the same study and are summarized in figure 1. The

Context
- Social-constructivist paradigm
- Rural or urban/marginal schools
- Telephone lines (25%)
- Fairly good conditions of physical infrastructure (93%)
- Average number of pupils per school is 237
- Each school has a computer laboratory (10 computers in average)

Input

Teacher characteristics
- Average staff members per school is 8 and the school principal.
- Classroom size 30 pupils in average.
- 90% teachers reported the promotion of social-constructivist paradigm or a mix of this paradigm and the behaviouristic paradigm.
- 58% of the teachers reported more than 16 years of experience.
- 46% of teacher reported an age > 45 years
- 59% teachers are female
- 72% obtained educational background in vocational institutions or Universities

Pupil characteristics
- Pupils' age M = 10 years at the start of the project in this study
- Low socio economical background of pupils.
- Low educated parents.
- 43% pupils are female
- Centralized school budget

Process
- No school assessment.
- Sporadically visits of district supervisors.
- Teachers trained by IEPSE promote social-constructivist and include ICT in their teaching.
- IEPSE teachers have had follow-up activities to support their teaching in technical and educational issues.
- Mindtools used in extra curricular activities during 2 years and 1 year later in regular school-hours.
- Parents and community are aware of the benefits of the project (annual activities).
- There is collaborative work among IEPSE teachers
- IEPSE teachers replicate the training to colleagues.
- Continuous IEPSE follow-up activities to support teachers in technological and educational issues.

Output
- IEPSE pupils reach higher levels of cognitive processing compared to other pupils that do not participate in the project.
- IEPSE pupils reach relatively higher mathematics scores compared to other pupils that do not participate in the project.
- IEPSE pupils show high self-esteem.
- IEPSE pupils demonstrate command in expressing their ideas and demonstrating their projects developed with mindtools
- IEPSE teachers show high self-esteem and responsibility.

Figure 1. The IEPSE-project described with the CIPO-school effectiveness model (based on Scheerens, 1992).

present study seeks to confirm the findings about the teaching and learning paradigm, but now based on a qualitative approach.

Input variables

Teacher characteristics

Several factors affecting the implementation of ICT in classroom teaching have been identified in the literature. However, according to Becker (2001), ICT skills of teachers are the strongest predictor of future ICT-use in the classroom. This is also confirmed in recent overview studies of Cox et al. (2004b) and Reynolds et al., (2003). Other important determinants are related to teachers' beliefs, the adoption of social constructivist teaching strategies (Smeets et al., 2001; Cox et al., 2004b; Reynolds et al., 2003; Bolhuis & Voeten, 2004; Fang, 1996), and individual characteristics such as technological innovativeness (Van Braak, 2001).

In our previous studies 90% of a group of teachers (*N*= 337) self-reported the promotion of the social constructivist or a mix of traditional and social-constructivist teaching principles in their classrooms and 89%-98% reported zero or low level knowledge of ICT and Internet skills. Other descriptive variables can be found in figure 1. A follow-up IEPSE-study involving 8 classes indicated that 80% of the teachers self-reported high levels of adoption of social-constructivist teaching strategies. No significant differences were found between IEPSE teachers and non-IEPSE teachers (Chiluiza-García et al., 2004a). In the present study, we will reconsider these research results, based on qualitative findings.

Pupil characteristics

IEPSE pupils are children that attend public rural or urban marginal schools. Their socio-economical background is very low; their parents are lowly educated people (COSASE, 2002). This study focused on pupils that attended to the 5th grade in year 2002. None of the pupils had previous knowledge of ICT or keyboard use. Information about the cognitive styles of the pupils in a previous study (*N* = 241), indicated that 24% are classified as field dependent, 35% field dependent/independent and 41% field-independent (Chiluiza & Valcke, 2004c). Next to gender, this variable was considered in the studies as potentially relevant co-variable.

Process variables

There is ample research about the impact of learning in Logo-based environment on the development of cognitive and metacognitive abilities of pupils (Cathcart, 1990; Chang, 1989; Clements, 1990; Clements & Nastasi, 1992; Enkenberg, 1990; Hoyles & Noss, 1990; Many, Lockard, Abrams, & Friker, 1991; Nastasi & Clements, 1994; Nastasi & Clements, 1992; Swan, 1991; Verschaffel, De Corte, & Schrooten, 1990). But the results of the studies are less satisfying. As stated by Clements and Meredith (1992), the teacher plays a crucial role as a facilitator and when a well structured planning has been implemented, positive results are observed. This brings us to the crucial importance of process variables.

This is congruent with the large emphasis in the IEPSE-project on intensive teacher training. Our previous studies about the actual adoption of social-constructivist teaching principles resulted in positive results; teachers that follow the IEPSE teacher training program reported high levels of adoption and this was confirmed through analysis of videotaped teaching behavior. Also their pupils reported their teachers have adopted to a higher extent constructivist teaching principles.

However, these levels of adoption remained rather modest (Chiluiza-García & Valcke, 2004b). Projects that aim at changing educational practices in teachers have encountered similar barriers to the ones found in IEPSE; i.e., teachers easily adopt the discourse of innovation and theories; however, they fail to implement these principles in the classroom (Tatto, 1999). Ross, Rolehiser & Hogaboam-Gray (1998) have found that more than one year of training is needed to expect teachers to adopt and integrate newly learned strategies; especially since the social constructivist paradigm has been qualified as a rather complex and sophisticated pedagogical paradigm (Conlon & Simpson, 2003; Tatto, 1999; Spector, 2001). Through the present study we try to confirm the previous findings.

Output variables

Cognitive achievements of the pupils

As was mentioned in the previous sections, several researchers reported the positive impact of Logo-based environments on cognitive and metacognitive outcomes of pupils.

In our research we could conclude that pupils that practiced with the Logo-mindtools demonstrated slightly higher levels of cognitive processing while working collaboratively; however, again, the majority of the IEPSE pupils' contributions remained lower (Chiluiza-García & Valcke, 2004c). These same pupils also reached very modest mathematics scores and not statistically significant in an international mathematics test as compared to pupils in control conditions (Chiluiza-García & Valcke, 2004d). The present study researches whether this positive impact is corroborated through a qualitative study approach.

Non cognitive achievements of pupils and teachers

Attitudinal observable changes in pupils and in their teachers are also other variables that are studied in this evaluation.

It has been found that pupils and teachers that engage in the use of ICT in their teaching and learning environment adopt better attitudes towards ICT and report higher self-esteem and levels of confidences with ICT (Cox et al., 2004b; Cox et al., 2004a). Next to the positive cognitive effects of Logo-based environments, also positive attitudinal changes have been observable and reported (Clements & Meredith, 1992; Chang, 1989; Valcke, 1991). In the present study we will seek evidence about these non-cognitive changes in both pupils and teachers.

Research design

Research questions

This study seeks to confirm findings of earlier quantitative studies about the IEPSE-project. The following questions are put forward: (a) What is the educational paradigm promoted by the educational authorities in Ecuador? (b) Is the social-constructivist paradigm actually adopted in the coastal Ecuadorian setting? (c) What are the attitudes of educational authorities and teachers about ICT use in the classrooms? (d) Is the IEPSE in-service teacher training component an alternative that fulfils coastal teachers educational needs? (e) What are the attitudinal differences found in IEPSE teachers as compared to other public primary teachers of the Peninsula region? (g) What are the attitudinal differences found in IEPSE pupils as compared to other public primary pupils

of the Peninsula region? In view of answering the research questions, based on the literature and the outcomes of our earlier research, we put forward the following working hypotheses:

1. The educational paradigm promoted by the educational authorities in Ecuador is based on social constructivist principles.

2. The educational paradigm is not adopted effectively by Ecuadorian teachers, or the educational authorities. Typical indicators are:
   a. Lack of knowledge about the concrete meaning of the paradigm and a lack of experience in putting it into practice.
   b. The majority of public Ecuadorian teachers do not promote typical social constructivist approaches such as team-work, problem-solving skills.
   c. There is a general demand for reform in Ecuadorian education with a focus upon changes in didactical approaches that are in line with social constructivism.

3. Information and Communication Technologies are seen by Ecuadorian teachers and educational authorities as a rich tool to foster teaching and learning in line with the social constructivist paradigm. But, there is a lack of resources and a lack of teacher training to adopt and implement the adequate teaching and learning strategies.

4. The quality of the teacher training offered by the IEPSE is in line with up-to-date quality indicators of ICT teacher training.

5. The teachers that are members of the IEPSE network show attitudinal differences in comparison to other public primary-school teachers: such as high responsibility, high self-esteem and leadership.

6. The pupils that have been taught by teachers receiving IEPSE-teacher training, show also high self-esteem, command in expressing their ideas or projects and in managing the educational environment they are used to work on. The pupils show happiness when presenting their accomplishments.

Research approach

Group interviews were based on a combination of three techniques: focus groups, the Delphi technique and the Metaplan® method (Aguilar, 2003; Schnelle & Stolz, 1977). These qualitative research methods were selected to gather a rich and large collection of information. The sessions started with the Metaplan® method that is especially helpful

to gather first information from each individual participant before they start discussing the topics in the group. This individual input is the starting point of the consecutive stages in the group interview. A better understanding of the participants' thinking about the topics discussed is achieved through this method (Mertens, 1998). Next, focus groups and the Delphi technique were used to discuss in depth the findings from the first phase. This technique is designed to take advantage of participants' creativity as well as the facilitating effects of group involvement and interaction.

Research sample

Five educational leaders were invited to participate in the forum (3 male and 2 female). The participants were experts with a vast educational experience in the Ecuadorian context as teacher trainers, educational district supervisors, high-school and school principals, school leaders and former representatives of the Ministry of Education at the regional level.

Procedure

Two weeks before the actual study, the participants were invited to visit individually several schools that are part of the IEPSE Project. They were asked to consider during their visit a number of key issues. The researchers supplied each participant with a set of questions to be discussed during the meeting with pupils and teachers of the IEPSE project, which were similar to the ones discussed during the meeting of the focus group. The names of the other participants were not disclosed before the start of the group meeting.

The day of the meeting, the members of the focus group were welcomed and informed about the research and the purposes of the conversation and discussion. The facilitator (a member of the IEPSE staff) introduced the members of the focus group to each other. They also received an explanation about the Delphi technique, the methodology used to gather data from the group and the procedure to get the consensus. In addition, a brief introduction of the following topics was presented: the basics of the IEPSE project, the goals of the project, the theoretical basis of the teacher training program. A video describing the target context, population characteristics, classroom activities and classes of IEPSE schools was projected after the presentation.

The facilitator of the forum presented the questions. These questions were ordered from very open and general to more focused questions that put forward critical issues of the IEPSE project. This procedure helped to prevent bias in the questions. After each question was raised, the participants had time to write –individually– down their answers on small cards; no names were put in the cards. The latter was designed to support confidentiality and freedom to express their opinions among the participants. The cards were collected, put on a whiteboard and structured according to the Metaplan® technique (Aguilar, 2003; Schnelle et al., 1977). Participants were asked to cluster answers, to prioritize topics, and/or to vote when they were expected to come to a shared conclusion. The detection of distinctions, similarities or patterns appearing in the answers to the questions was stimulated by the facilitator. Decisions or conclusions were immediately made explicit in the information on the whiteboard. The Metaplan method was in this perspective a helpful technique to achieve consensus and to make it very explicit. Pictures were taken of the consecutive discussion outcomes on the whiteboard. A researcher was also taking notes of the discussion and transcribing the individual and consensus contributions during the whole process. In addition, short videos were recorded for further review and analysis. The meeting lasted for 6 hours.

At the end of the meeting the facilitator and the participants reviewed the results of the discussions as a final feedback to the participants of the meeting.

Results and discussion

The results are structured along the different working hypotheses and building on the list of questions posed to the participants. At the end of each list of questions, a final conclusion in relation to the hypothesis is presented.

Question in relation to working hypothesis 1

Question: What is the educational paradigm promoted by the Ecuadorian educational authorities at the national and provincial level?
The following themes were central in the answer to this question: contextualized learning, ecologically sound, situated learning, the constructivist paradigm (social constructivism). This list of themes are mirrored in what it is expected a constructivist teacher creates in his/her classroom e.g., self-examination and self-reflection; inclusion

of alternate or multiple views; generation of meaningful and contextualized learning, etc. (Bednar, Cunningham, Duffy & Perry, 1992; Jonassen, Howland, Moore & Marra, 2003).

This list of themes confirms working hypothesis 1. The result is also in line with the policy guideline put forward by the Ministry of Education regarding teaching principles that must be promoted in teacher education (MEC, 2002).

Questions in relation to working hypothesis 2

It is to be stressed that the questions raised in relation to this hypothesis deal with the larger Ecuadorian educational context and do not directly build on the schools and teachers in the IEPSE-project. The answers to the questions help to ground the need for educational changes and innovations at classroom level (teachers and pupils), such as have been adopted in the IEPSE-project.

Question: What are the two most common difficulties in the application of this type of teaching and learning in the Ecuadorian context?
In general, the educational leaders have a deep lack of knowledge about "how" to apply effectively the paradigm in the classroom. There is a lack of training and competencies in the teachers about topics related to the application of the current paradigm.

Question: What are the two most common teaching strategies applied in the Ecuadorian public schools?
Ecuadorian teachers focus too exclusively on knowledge reproduction and memorization as learning strategies. Knowledge is presented in a thematic way.

Question: Mention two aspects or characteristics of how these strategies contribute to the effective development of skills such as critical thinking and problem solving
The group agreed that there is currently no enrichment of thinking skills considering the focus on knowledge reproduction and memorization.

Question: Mention two aspects or characteristics of how these strategies hinder the effective development of skills such as critical thinking and problem solving
The following feedback was given by the participants: (a) they delay the development of lateral thinking; (b) they hamper the thinking development process; (c) they contribute to the lack of thinking skills and abilities demonstrated by our children; (d) the memorization of concepts do not contribute to think creatively; (e) the "reductionist"

teacher follows one single teaching format; (f) they contribute to the lack of communication or interaction between the teacher and the student; (g) the memorization without reflection stops the development of a critical and creative student.

Discussion of the individual input resulted in a clear list that was accepted unanimously by all participants. They concluded that currently –in the Ecuadorian context- there are hardly teaching activities that foster thinking skills and/or critical analysis skills. The strategies observed do not include techniques that develop lateral thinking.

Question: Mention two factors that show how these strategies strengthen cooperative work (work group) in the classroom

The panelists agreed in that the current teaching strategies adopted by the teachers, do not create opportunities that generate cooperative work

Question: Mention two factors that show how these strategies weaken cooperative work (work group) in the classroom

Discussion among the focus group members resulted in the following list: (a) individualized learning activities do not promote team-work; (b) due to the characteristics of these strategies there is lack of interaction that could impede the communication and cohesion in the group.

Question: Give some examples of effective use of teaching strategies that develop the aforementioned skills. Consider the Ecuadorian context when giving examples.

A discussion among the panel members resulted in the following list of concrete examples: (a) educational projects developed in teams that produce micro-enterprises and social projects. These projects are developed in private primary and secondary schools that are part of CORPEDUCAR (Non governmental organization NGO); (b) regular discussion forums with pupils, through student government in the classroom; (c) student team-work that contributes to problem solving and in which the pupils are obliged to negotiate and solve conflicts; (d) the approach adopted in the IEPSE project; (e) the approach adopted in the Project MEC-PLAN (NGO) that promotes the use of games in the solution of problems and that expects pupils to deal with multiple answers and solutions for a problem.

The list of answers helped the researchers to corroborate what was previously found when actual Peninsula region classes were observed. Ecuadorian teachers –from this region- do yet not promote actively social-constructivism in their classroom. They

demonstrate a lack of knowledge about the teaching principles of the paradigm. In addition, the members of the group also pointed out that this lack of knowledge is not only observable at the micro level but at the meso level in school principals or educational leaders. These results also coincide with was stated by the Ministry of Education in relation to the inadequate status of teacher proficiency that is found in Ecuador (MEC, 2002). Finally, the few initiatives of effective use of constructivist teaching principles were found to be promoted by non-governmental organizations or universities working in partnerships with governmental organizations.

Questions in relation to working hypothesis 3

Question: Do you think the teachers easily accept the incorporation of ICT as a teaching/learning tool in the classroom?
The following list of quotes, illustrates the consensus among the focus group members.
"Yes; however, it is necessary: teachers' training, monitoring and follow-up training activities."
"I do totally agree. It is time for innovation."
"Yes, but it is not so easy."
"Yes, if they are trained."
"This will be accepted, but…. more and adequate training is needed"
The members of the focus group agreed that teachers will accept the implementation of ICT in the teaching learning process, but only through a process that includes: persuasion, training, monitoring and follow-up activities.

Question: Mention two factors that might promote and two factors that might inhibit ICT acceptance.
After the discussion the members of the group agreed in the following two factors that promote ICT acceptance: (a) to hire a responsible institution that guarantees an efficient training program, (b) to guarantee easy access to updated information and ICT. In addition, after consensus had been reached, the group agreed upon two factors that inhibit ICT acceptance: (a) non-committed institutional leadership, (b) inadequate policies of the teachers' unions.

Question: Give some examples of effective use of ICT as a tool for teaching/learning in the classroom; according to what you see, hear or do.

The group decided upon the following key examples: (a) development of projects -at the micro level- using educational software in primary schools, part of the IEPSE project (a list of concrete schools was given); (b) the [Maestr@s.com](#) project which is a large scale project promoted by the Ministry of education to reduce the digital divide in Ecuadorian teachers.

Question: What skills have been inhibited and/or stimulated in pupils through the use of ICT in the classroom? The group agreed in that the use of ICT in the classroom can stimulate the following skills: (a) interaction between teachers, pupils and the context; (b) creativity; (c) inquiry-based learning. In addition, the group agreed that the following skills might be inhibited by the use of ICT in the classrooms: (a) when the teacher is not applying the appropriate teaching strategies, the work in small computer-based groups might impede the interaction of the micro-groups with the general group; (b) equal participation and access of all the pupils to computers; in part due to the lack of availability of more ICT.

Question: How might schools contribute in developing these skills with the use of ICT? After discussion the group reached the following agreement: (a) strengthen the training of teachers to acquire technological and didactical competencies; (b) include the use of ICT in the strategic plan and in the institutional educational program of each school or educational institution.

Question: How teachers might contribute in developing these skills with the use of ICT? The group consensus related to this question was: (a) teachers have to dedicate more time to ICT training and didactical training in view of designing and applying active teaching techniques supported by ICT and (b) teachers have to change their attitudes towards instruction and technology.

The answers to the questions in relation to the working hypothesis 3, allow the researchers to corroborate somehow the findings of their earlier studies: (a) adequate training is needed to the truly inclusion of ICT in the classroom; but, access to information and technology has to be guaranteed; (b) teachers attitudes play an important role in the inclusion of ICT; teachers has to change their attitudes towards training, since they do not dedicate time for continuous education; (c) Ecuadorian teacher attitudes towards ICT are positive, the perception that ICT can benefit children's learning has been recognized; (d) leadership and support for training from the school/institution are also required; the incorporation of ICT as a school policy is key in the effective introduction of ICT in schools. The members of the focus group identified

factors that have been reported as important in the actual adoption of ICT in the classroom: teachers training is a key issue (Knierzinger, Røsvick, & Schmidt, 2002); leadership and ICT policy in schools (Reynolds et al., 2003); and teacher attitudes (Conlon et al., 2003). These factors were also identified in previous research about IEPSE project reported in (Chiluiza-García et al., 2004a). In addition, IEPSE was identified as a good example of the effective use of ICT; especially, regarding the adequate role of the teacher as a mediator between pupils and ICT-learning environments.

Questions in relation to working hypothesis 4, focusing on the IEPSE project

Question: Mention three factors that promote or inhibit the success of the type of training the teachers in the IEPSE Project receive.

The members of the group agreed on the following factors that promote the success of IEPSE training: (a) effective induction to change of attitudes in the teachers; (b) the quality of the training approach and the training content; (c) the support, follow-up and continued evaluation performed by the sponsors.

On the other hand, the panelists also include the following factors that might inhibit the success of the IEPSE training: (a) teachers and pupils do not have enough access to technological and pedagogical resources; (b) the lack of commitment at school or institutional level; (c) the lack of commitment of principals or educational authorities in some schools.

Question: Suggest recommendations about the training the teachers received in the IEPSE Project.

The members of the focus group developed a list of recommendations they listed as follows: (a) training and (b) development or expansion of the project. Regarding the training they pointed out that it is necessary to put more emphasis on the explicit development of thinking skills. They suggested on-site training and the promotion of exchange of experiences between IEPSE and non-IEPSE teachers. Concerning the development or expansion of the project, the group suggested that the IEPSE initiative should be replicated in other contexts (not only in the Ecuadorian Peninsula region). They advised the IEPSE staff to look for partnerships with other organizations and finally suggested to include more closely communities members (families, parents, companies).

The answers gathered with the questions in relation to the working hypothesis 4 allow the researchers to complement the preliminary findings put forward in relation to hypothesis 3. Especially, the elements put forward above the recommendations corroborate the results found in Chiluiza-García et al. (2004a). On the other hand, the relative successful results of the IEPSE project warn the researchers about an aspect only marginally included in the project: fostering the diffusion, sustainability and management of the project. The projects have e.g., to become part of a school policy or national policy (Tearle, 2003; Demetriadis et al., 2003). Put in another way, once the capacity building of the IEPSE-teachers has reached a certain development level, it is critical to put them in contact with other staff members in order to become 'moral change agents' as suggested by Fullan (2001). However, this topic has not been addressed by the researchers in this study. It is therefore suggested to include it in the further implementation of the IEPSE project.

Questions in relation to working Hypothesis 5

Question: Give some examples of the differences (if any) in the attitudes demonstrated by the IEPSE teachers and other teachers from public-rural schools not participating in the project.

After discussion, the panel members agreed that IEPSE-teachers show the following characteristics that differ from the ones found generally in teachers of coastal Ecuador: (a) high self-esteem; (b) they differ from other teachers outside the IEPSE-project; (c) they show satisfaction about their achievements; (d) they show competencies and confidence in what they do; they show a high degree of responsibility and commitment; (e) they are process oriented (projects and classes); (g) they demonstrate effective, adequate and affective communication with their pupils; (h) they work with pride and happiness; (i) they frequently participate in teams; (j) they are process planners (projects and classes)

From these responses we underscore firstly those related to the teachers as planners, process orientation and effective and affective communicators. These differences, observed by this group of independent external observers, are helpful to triangulate our previous findings about the high adoption of social constructivist teaching strategies by IEPSE-teachers. The IEPSE training emphasized the structured planning of the use of resources and teaching strategies in the classroom. In addition,

the teachers learned to create active learning environments. This was also identified by the members of the focus group. As stated earlier, these corroborate our previous results (Chiluiza-García et al., 2004b). A second set of attitudinal differences were perceived by the panelists, such as teacher satisfaction, commitment, high-self esteem and team-work. This set of critical teacher characteristics are also related to successful ICT-adoption (Becker, 2001; Gonzales, Picket, Hupert, & Martin, 2002; Ruthven, Hennessy, & Deaney, in press).

Questions in relation to working Hypothesis 6

Give some examples of the differences (if any) in the attitudes demonstrated by the pupils that are part of the IEPSE project and other pupils not participating in this initiative.

After discussion, the panel members agreed that IEPSE-pupils show the following characteristics that differ from the non IEPSE-pupils: (a) pupils are communicative and participative; (b) they have enhanced their verbal expression and express themselves more easily; (c) they work and participate in collaborative teams; (d) they behave like investigators/researchers; (e) they look happy, spontaneous and reflect satisfaction about their achievements; (f) there is an evident empathy among teachers and pupils; (g) pupils show self-confidence; (h) they show mutual support.

From these results, the researchers conclude that positive attitudinal differences were found in pupils that participated in the IEPSE project. More specifically, the researchers underscore the collaborative work in teams, the observation about investigators/researchers attitudes and the positive attitude towards their achievements. These attitudes are also found in other successful ICT-projects (Cox et al., 2004a; Hennessy, 2000; Barak, Waks, & Doppelt, 2000). In addition, other researchers also found that ICT and Logo-based environments facilitate peer-interaction and general intellectual developments (Chang, 1989; Clements et al., 1992; Ibrani Shahrimin & Butterworth, 2001; Svensson, 2000; Valcke, 1991). The communicative skills observed by the members of the focus group were not researched in the previous IEPSE-studies.

Reflections about the study and the results

In the quantitative studies, there was a strong focus on analyzing the impact on pupil performance in mathematics and their cognitive processing. This study did not focus on this type of impact. Qualitative approaches are less adequate to study this type of results. Other research designs should be adopted to confirm these findings. This brings us to a number of reflections about the research design adopted in this study. In general, the themes broached by the experts and their answers to the questions were helpful to back the results found in the quantitative IEPSE-studies. But these qualitative data are based on perceptions, ideas or impressions. It is possible that personal bias of the experts has influenced their input to the study. An additional remark can be made about the questions that structured the discussions. Although they were carefully ordered and high effort was put in posing non-suggestive questions, it is not impossible that they might have affected tendencies in the expert reactions. Moreover, a number of issues have not or hardly been raised in the discussions. Critical policy variables and contextual issues that are being reported in ICT-studies were hardly touched upon. Although the session lasted about 6 hours, more sessions might have been needed and maybe involving another group of experts to identify additional key elements. Next, the contact with, experience of and knowledge about the IEPSE-project were limited. At the one hand, the opinion of independent experts is a positive element. But at the other hand, the experts based their input on a limited knowledge base about the project. We could also not control the way, the amount and the nature of the interaction of the experts with the teachers and pupils while visiting the schools. But as stated earlier, it was not the intention to set up an independent qualitative study about the IEPSE-project. The study was proposed to find additional evidence to confirm earlier results and/or put these results in a broader perspective.

It was also interesting to receive from the experts ideas about the future of the project. Especially the suggestions about actions to foster the dissemination and up scaling of the project were valuable.

Conclusions

The present study tried to confirm the results of earlier quantitative studies about the impact of the IEPSE project. From the results, it can be concluded that the experts involved in the discussion session present ideas, views and perspectives that are consistent with some of the findings of earlier IEPSE studies. More specifically, the ICT teacher training program was judged to answer some of the training needs of teachers from the Peninsula region and to be in line with the national demands about teacher training. However, more research is needed to generalize the findings of this research. The high levels of adoption of social-constructivist teaching were also substantiated by this study. Positive changes in attitudes were observed, both in pupils and teachers; among others changes in attitudes about working together, planning, and self-confidence. Conversely, the modest cognitive learning outcomes found in previous studies could not be corroborated through the qualitative methodology. Further alternative research design should be adopted to focus on corroborating these findings. Finally, the weaknesses of the present study were helpful to identify directions for future research.

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General discussion and conclusions

The aim of this dissertation was to study the effect of an ICT teacher training programme, based on the social constructivist paradigm, on the learning skills of pupils in the primary schools in the Ecuadorian setting. In the introduction section of this thesis, we presented three problems that arise from the analysis of earlier research that focus on the impact of ICT on teaching and learning. These problems are related to the following: (a) the study of the particular relationship between the ICT teacher training and the expected pupil outcomes in ICT-based environments; (b) questions about what is actually measured when analyzing the impact of ICT on pupil performance; (c) questions about the methodology to study the impact of ICT enhanced educational environments on pupils and teachers.

We tried to consider these three problems in the design of seven studies. For the purpose of these studies, the general research problem as presented in the title of this thesis was broken down into five research questions:

1. Is the content of the IEPSE ICT teacher training programme and its instructional approach in line with international trends in teacher training?

2. Is the content of the IEPSE teacher-training programme relevant to the educational needs of teachers in the Santa Elena Peninsula context in Ecuador?

3. What is the long-term impact of the training programme on the teaching strategies of IEPSE-teachers in their classroom context?

4. What is the impact over time of the IEPSE project - and the subsequent changes in the learning environment - on the actual cognitive processing of the pupils and on the mathematics learning outcomes of 5th grade pupils?

5. Can the results of the quantitative studies of IEPSE be corroborated by adopting qualitative methods?

These research questions were tackled in seven studies that were reported and discussed in the five preceding chapters. In this section we bring together the results of these chapters. Next, we present an overall discussion of the results in view of the 5 research questions. The chapter concludes with an account of the limitations of the different studies, and the implications of the findings.

Overview of the results

Chapter 1 focused on answering the first research question. A review of international standards, benchmarks, and best practices of ICT-effective teaching resulted in the delineation of 9 clusters of competencies: (a) basic ICT and productivity skills; (b) using ICT as a mindtool and for cooperation/communication; (c) selection, assessment and evaluation of ICT products; (d) adoption of a variety of instructional/pedagogical strategies and ICT resources for learning, especially those that promote constructivist strategies; (e) design and production of learning materials integrating the use of ICT; (f) evaluation of teaching and learning approaches with ICT; (g) teaching through or with ICT to enhance learning in different settings.; (h) student-centered teaching considering learning styles supported by ICT; (i) management social-ethical issues with ICT. It was determined that the IEPSE programme encompasses 7 out of the 9 clusters of competencies found at the international level, and therefore its contents is considered in line with current international trends in ICT teacher training. In addition, a brief review of the literature about current teacher training approaches helped us to contrast these approaches with those present in the IEPSE training. From this analysis we could deduce the constructivist nature of the teacher training; strategies that are found in present-day trends in training approaches about pre-service and in-service training of teachers are also found in the IEPSE programme. A strong component of the training was the actual demonstration and adoption of the social constructivist paradigm. We found that IEPSE training approach is also in line with the state-of-the art approaches to the professional development of teachers.

Finally, this chapter aimed to answer research question 2. A small descriptive study of the characteristics of Ecuadorian teachers in the Peninsula region helped us to established teacher characteristics, and perceptions of teachers about their ICT-competences and adoption of constructivist teaching strategies. In general, these teachers are aware about their low ICT-skills; they found ICT use relevant in the teaching-learning process; the majority is not recently involved in attending to teacher training (49%), or only attends to seminars about the educational reform of 1992. In relation to teaching principles, the majority of teachers promotes a *curious-mix* of teaching strategies –constructivist and traditional strategies- (49%), whereas an important group of teachers (41%) promotes the constructivist teaching principles.

Chapter 2 integrated the results of study 3 and study 4. It analyzed the long-term impact of IEPSE training programme -after 2 and 3 years of initiated the training- on the teaching practices of the experimental and control teachers. It was found -through actual observation of teaching activities in science classes- that IEPSE teachers adopted to a significantly higher extent social-constructivist teaching principles in their practices. Though, overall relatively low levels of adoption were observed (CTI and video analysis). Regarding teacher ratings about their own adoption of social-constructivist teaching principles in their science classroom practice, no significant differences were found between the research conditions. Interestingly, pupil perceptions about the adoption of the principles by their teachers aligned with the actual levels of adoption observed by the researchers in the classroom setting. Pupils with IEPSE teachers or with teachers of schools in the IEPSE-project report higher average ratings about their perception of adoption of constructivist teaching principles by their teachers (large effect sizes were observed) than the pupils of non-IEPSE teachers as compared to pupils in the control condition outside the IEPSE-project. Finally, it was found that teacher ratings about their own adoption of social-constructivist teaching principles were higher than the actual adoption observed in the classrooms; this finding is consistently found when analyzing the results obtained in year 2002 and 2003 in the same chapter.

The impact -over time- of the IEPSE project on pupil outcomes was studied in chapter 3 and chapter 4. The following variables and their relationship with pupils' outcomes were studied: experimental treatment, average ratings about their perception of adoption of constructivist teaching principles by their teachers, and individual differences between pupils (cognitive style and gender).

Chapter 3 aimed to answer partially research question 4. Levels of cognitive processing were measured while pupils were working collaboratively on a near transfer task in a non ICT based learning environment. This measurement was carried out both in 2002 and 2003; thus allowing to study the impact over time. Regarding the proportions of levels of cognitive processing observed in the different conditions, level 1 (sharing and comparing information) was predominant, followed by level 3 (negotiation of meaning/co-construction of knowledge). These results are consistent in 2002 and 2003. Higher levels of cognitive processing were scarcely observed; however, only IEPSE pupils reached such higher levels in 2002 and 2003.

The analysis of the data gathered in 2002 did not reflect significant differences in levels of cognitive processing between pupils in the research conditions. But, one school year later (2003), IEPSE-pupils demonstrated a small but significant change in the distribution of proportions of levels of cognitive processing. However, contrary to our expectations, the final levels of cognitive processing were lower in the last year of the experiment. The hypothesis that IEPSE pupils would demonstrate higher levels of cognitive processing in 2003 as compared to 2002 could not be confirmed.

Concerning pupils' characteristics, gender did not affect the cognitive processing levels in the different conditions. But cognitive style had a significant impact. Pupils reflecting a field independent cognitive style reached higher levels of cognitive processing as compared to pupils with a field dependent cognitive style; this is consistently observed in 2002 and 2003.

Finally, we hypothesized that the average ratings of social-constructivist teaching perceived by pupils -measured in chapter 2- are positively related to the levels of cognitive processing. The data helped us to build a predictive model. This model predicted more than 80% of the cases; it shows that the higher the perception of pupils about the average adoption of social-constructivist teaching by their teachers, the higher the odds pupils are categorized in a high level of cognitive processing. However, given the small number of pupil behaviors in the high level category, we could not draw a definite and clear conclusion in relation to the hypothesis put forward.

Chapter 4 focused on the study of the impact over time of the IEPSE project on pupils' mathematics scores. This chapter aimed to complement the answer of research question 4. The mathematics scores of pupils were measured -administering an internationally acknowledged mathematics performance test- after 2 and 3 school years of being initiated to the IEPSE project. Results of chapter 3 about the levels of cognitive processing demonstrated by pupils were also incorporated in this study. Regarding the final mathematics scores, IEPSE pupils obtained significantly higher mathematics scores when compared to non-IEPSE pupils. More specifically, pupils in experimental condition B reached slightly higher mathematics scores than pupils in the other two conditions. The differences among IEPSE pupils and those in the control condition were much less pronounced in the next year. Although some differences were detected, overall pupils showed low mastery of mathematics knowledge in the different conditions in both school years.

The longitudinal study of the mathematics scores obtained after 2 and 3 years of treatment showed that only marginal or no differences were found between pupils in the different conditions.

Regarding to pupils' characteristics -comparable to chapter 3- gender does not interact with the mathematics scores of pupils in the different conditions. However, cognitive style had a significant impact. Pupils with a field independent cognitive style obtained higher mathematics scores as compared to field dependent pupils, both in 2002 and 2003. No significant interaction with cognitive style and gender were detected.

In regard to the degree of adoption of social-constructivist teaching perceived by pupils -as reported in chapter 2- and its relation with mathematics scores of the pupils, no significant relationship was found.

Finally, we hypothesized about a positive relation between the mean levels of cognitive processing demonstrated by pupils and their mathematics scores. The results show a positive and significant relationship between these two variables, both in 2002 and 2003.

Chapter 5 focused on answering research question 5. This chapter was based on a qualitative study that aimed to corroborate the findings in previous chapters. A group of educational leaders participated in this seventh study. The following findings are the result of this study.

Regarding to the context of Ecuadorian teachers from the Peninsula region, the educational leaders indicated that Ecuadorian teachers yet do not promote actively the social-constructivism in their classroom. Moreover, they demonstrate a lack of knowledge about the teaching principles related to this paradigm. In addition, the members of the group pointed out that this lack of knowledge is observable not only at the micro level but also at the meso level in school principals and/or educational leaders. But they also report -in sharp contrast to the daily teaching practices- that this paradigm is clearly promoted by the Ecuadorian educational authorities.

Concerning factors that hindered or promoted the use of ICT, the educational leaders identified the following: (a) adequate training and access to technology is needed; (b) the need to change teachers attitudes towards training; (c) teachers attitudes towards ICT are positive; (d) leadership and support for training are also required.

In relation to the key factors of the relative success of the IEPSE training, the following features were identified: (a) effective induction to change in attitudes of the teachers; (b) the quality of the training offered by IEPSE (both the training approaches and the

curriculum content); (c) the provision of support and follow-up activities. The group also suggested certain factors that warn the researchers about an aspect only marginally included in the project: fostering the diffusion, sustainability and management of the project.

Concerning characteristics of IEPSE teachers that differ from the ones found in other coastal Ecuadorian teachers, external observers recognized the following: teachers as planners, teachers as adopters of a process orientation and as effective and affective communicators. Other set of attitudinal differences were perceived by the panel members, including higher teacher satisfaction, clear commitment, a high-self esteem, and the adoption of team work.

In regard to characteristics of IEPSE pupils that differ from the ones found in other coastal Ecuadorian pupils, the group pointed out the following: (a) more collaborative (b) with enhanced communicative skills, (c) that have adopted the behavior of a researcher/investigator, (d) that show self-confidence, and (e) that show mutual support. In general positive attitudes were found by the external researchers in teachers and pupils that participated in the IEPSE project. Moreover, positive features and areas for improvement of the IEPSE training were also identified.

A general discussion of these overall findings will be presented in the next section.

General Discussion

In chapter 1 we positioned the IEPSE teacher training programme at the international level. It was found that the contents of the IEPSE training are in line with the international trends in ICT teacher training. Next, the descriptive analysis of the IEPSE educational approach help to sustain the conclusion that the IEPSE-teacher training is in line with social constructivist principles and reflects current trends in teacher training approaches and conceptions; Thirdly - based on the results of the survey about the characteristics of teachers in Peninsula region – we come to the conclusion that the content of the IEPSE programme might suit the training needs of teachers in the Peninsula region.

In chapter 2 the long-term impact of the IEPSE teacher training was evaluated. This evaluation aimed at answering research question 3. The positive results found in 2003 confirmed the trend discovered in 2002. IEPSE teachers differ significantly from

other teachers in the study (hypotheses $3a_1$). Moreover, an increase in the scores (CTI) from one year to the next one helped the research team to find that a significant change in time in IEPSE teachers teaching has occurred (hypotheses $3c_1$). This finding can be explained by the *additional time* teachers had to reflect about the newly learned teaching strategies and to accommodate and to put into practice their own set of teaching strategies. Time is critical as well as nurturing to cope with challenging environments. The results are clearly in line with other ICT teacher training research that purports on this time issue.

The fact that teachers still obtained low scores in the CTI is an important finding. This might be linked to the slow process of adoption of new assumptions and perceptions about teaching and learning. It is also explained by the difficulties teachers experience to understand and untie a pedagogical model that is generally qualified as rather complex and sophisticated. In addition, it was stated that the context surrounding IEPSE teachers might have been sub-optimal to foster the further development of the innovations based on ICT. It was stated that maybe too few teachers per school were involved in the project. In addition no institutional policy or innovative leadership was observed in these school contexts. In more recent studies, the crucial importance of (ICT-related) school policies has been detected and stated. These issues were not included in the IEPSE studies.

The relatively positive results were assessed by means of both teacher ratings about their own adoption of social-constructivist teaching and pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles

Regarding the self-ratings of teachers, a parallel administration of the CLES-test shows that 80% of the teachers in control conditions report a high rating of adoption of constructivist teaching; consequently, significant differences were not found between teachers in the conditions in year 2002 nor in year 2003 (hypothesis $3a_2$). Thus, a change over time could not be detected on teachers' self-reports of adoption of constructivist teaching (hypothesis $3c_2$).

However, the findings about pupil perceptions helped to confirm the hypotheses. IEPSE-pupil average ratings about their perceptions of the adoption of social-constructivist teaching principles by their teachers in science classroom practice are higher as compared to non IEPSE-pupil ratings (hypothesis 3b).

The above results were contrasted with the ones gathered through the observation of actual teaching. On the one hand, the high correlations between the CTI-scores (video

analysis) and the CLES average ratings of the pupils help the researchers to underscore the reliability of the pupil perceptions as measured with the CLES and the importance of such measurements. On the other hand, the too high CLES self-ratings of teachers warned the researchers about the potential bias in or too positive self-perceptions of teachers. Only the IEPSE trained teachers demonstrated a more realistic estimation of their degree of adoption of social-constructivist principles. The research team relates this finding to the fact that some meaning and sense making have occurred during this learning process lasting more than 2 years.

Based on the results and the analysis the null hypotheses $3a_1$, $3b$ and $3c_1$ were rejected and the null hypotheses $3a_2$ and $3c_2$ could not be rejected. Thus, the researchers can conclude that the IEPSE training affected positively teachers' teaching.

Relating the strengths of studies 3 and 4, we can point out firstly, that the quasi-experimental treatment was established in regular classroom settings. Secondly, the observation of the actual teaching behavior of teachers in their classroom is another positive strength of this study. Thirdly, the varied approach to measure the levels of adoption of social-constructivist principles -through observation and self-ratings- is another strength of this study. In addition, another alternate measure was taken to contrast teachers' behaviors in the classroom i.e. pupils' perceptions. Finally, the longitudinal characteristic of study 4 is another strong feature of the research reported in chapter 2.

Chapter 3 and 4 were strongly related to one another, they aimed at answering research question 4.

Chapter 3 examined the impact of the IEPSE project over time on pupils' levels of cognitive processing. It was observed that already at the start of the study, IEPSE pupils demonstrated slightly higher levels of cognitive processing, though no significant differences were observed. However, one year later the difference in levels of cognitive had become significant; but it has to be pointed out that difference was rather small (hypothesis $4a_1$). The mindtools used in the quasi-experimental treatment seemed to foster higher levels of cognitive processing (hypothesis $4c_1$). The findings of the study are in line with previous research carried out during the 80's and 90's.

Despite the positive results, the impact over time on the levels of cognitive processing was not clear (hypothesis $4e_1$). Even though IEPSE pupils demonstrated cognitive processing at all levels, the proportions of higher levels of processing were not much higher in the last year of the study than the ones initially observed. In clear contrast, the

pupils in the control condition only reflected behavior coded at level 1 in the model. As it was explained in this chapter, the authentic context in which the studies were set up, might in part explain the results. A long strike of the teachers might have affected overall school functioning and classroom performance in 2003.

Our findings could not be compared with up-to-date research. However, partial research evidence of the 80's and 90's also reported difficulties in detecting near transfer effects of Logo-based learning experiences. This previous research points at the following variables to reach transfer: the hours spent by pupils in the experimental treatment and the frequency of attendance to the Logo-based lessons, as well as specific training for problem-solving. A number of about 60 hours of intensive treatment has been identified as conditional. This was not the case in our experiments. Although IEPSE pupils also worked with the Logo-environments for about 60 hours, this was during a much longer period of time and with intermittency due to e.g., a long teachers' strike in the Ecuadorian school setting at end of the school year 2003. No conclusion could be presented about the relationship between the perceived constructivist teaching principles promoted in the classroom and the levels of cognitive processing (hypothesis $4c_1$). This can be brought back to the overall low level of cognitive processing observed in the activities. These results could not be contrasted with up-to-date research.

The results about the individual differences and its relations with cognitive processing found in chapter 3 will be discussed below, along with the strengths of study 6.

Chapter 4 studied the impact of IEPSE project over time on pupils' mathematics learning. Differences between the mathematics scores of IEPSE pupils were already present at the start of the study. The trend continued in the next school year; however, no significant differences were found (hypothesis $4a_2$). The impact over time could not be confirmed in this study (hypothesis $4e_2$). One reason related to these findings might be the fact that the mindtool activities in the IEPSE project covered a wide variety of school related problems. The direct relationship with the mathematics domain tested with the TIMSS test might have been too low. Of course, due to the nature of the Logo-tools, solution of the problems and the graphical representation always implied the application of mathematical knowledge and procedure. But the core of the learning problems, tackled in the collaborative settings, was in many cases not mathematics related.

The mean levels of cognitive processing demonstrated by pupils and their mathematics scores were positively and significantly interrelated (hypothesis $4d$). It has been found

that pupils, who attend classes with a strong emphasis on reasoning and problem-solving, reach higher scores on TIMSS tests. Additionally, other studies link the collaborative context to a positive cognitive development in mathematics attainment. Few studies have been found in the literature that focus on this specific hypothesis and/or helpful to corroborate or contradict the present results.

Pupil average perceptions of their teachers adoption of social-constructivist teaching strategies was not related to their mathematics scores in the IEPSE study (hypothesis $4c_2$). A possible explanation for these results might be related to the fact that the pupils were asked to rate the teaching behavior of their teachers in science classes. The kind of teaching in these classes can still be restricted to the use of pre-structured science-manuals. A too strong focus on manual-led teaching might have hindered the adoption of the innovative teaching strategies.

Finally, the individual differences of pupils were examined in chapter 4 as well as in chapter 3. It was found that gender was not related to mathematics scores or to the levels of cognitive processing (hypotheses $4b_1$ and $4b_2$). Moreover, pieces of recent research point out to a consistent trend, gender differences are decreasing in mathematics scores. The analysis of the interaction between gender and levels of cognitive processing has not been reported in up-to-date research.

Pupils with a field independent cognitive style reached higher mathematics scores as well as higher levels of cognitive processing (hypotheses $4b_1$ and $4b_2$). Most of our findings corroborated the knowledge about field independent pupils and their mathematics outcomes or their abilities to mirror independent cognitive control and their preferences of analytical reasoning.

Based on the results and analysis related to chapter 3 and 4, the null hypotheses $4a_1$, $4b_1$, $4b_2$, and $4d$ were rejected, the null hypotheses $4a_2$, $4c_2$ and $4e_1$, and $4e_2$ could not be rejected, and no decisive conclusion can be taken regarding null hypothesis $4c_1$.

Overall, the impact of IEPSE over time on pupils has not been significant and a positive impact has only been detected for a small subset of the hypotheses. The transfer value of Logo-based learning activities to learn mathematics can be questioned; though, the potentialities for making positive cognitive development are promising. It is important to state here again that a long strike of the teachers in the last months of this research in the Ecuadorian setting could have influenced negatively the studies reported in chapter 3 and 4. The researchers believe that this event could certainly have affected the mathematics scores obtained in the year 2003.

Finally, the strengths of study 5 and study 6 can be summarized as follows. The impact over time of this innovative project has been studied. The studies were performed in natural school settings. Not only outcomes measures have been reported (mathematics scores), additionally the actual process of knowledge construction (levels of cognitive processing) in near transfer tasks has been studied through analysis of observations of collaborative activities. Fair comparisons of teacher and pupil behavior in non-ICT environments and the use of mathematics tests (TIMSS) not designed by the researchers, guaranteed a sound research treatment of actors in all research conditions.

The study reported in chapter 5 helped to answer research question 5. Qualitative methods were used to corroborate the findings of the previous chapters. We could confirm that the IEPSE training programme fulfils partially the training needs of teachers from the Peninsula region. The training approach of IEPSE was also in line with the Ecuadorian educational guidelines for training teachers, promoted by the Ministry of education. The results of chapters 1 and 2 about the higher extent of adoption of social-constructivist teaching were also substantiated by the results of this study. Positive attitudinal changes were observed, both in pupils and teachers. These findings are in line with results of previous research. However, the cognitive learning outcomes found in previous chapters could not be studied or questioned through the qualitative methodology used. Based on the analysis of the results, the null hypothesis 5 was tentatively rejected. Finally, input of the experts about the future of the project were also some of the valuable outputs of chapter 5; e.g., the suggestions about actions to foster the dissemination and the up-scaling of the project.

Limitations of the studies

The results of this dissertation must be considered in the light of a few limitations. The following six concerns apply to most studies, with the exception of study 1 and study 7.

First, the studies presented through chapters 2 to 4 were designed as quasi-experimental treatments. The sampling approach focused on schools and teachers that were linked/not linked to the IEPSE programme and attended/not attended to the training. This implies that it was not possible to carry out a selection based on stratification variables that reflect teacher characteristics. Moreover, we involved pupils of the classes that were the responsibility of the selected teachers. This might have

affected the design and the research results. For instance, the low scores in mathematics might not be entirely representative of the participants in the Peninsula setting.

Second, no baseline about the several variables studied in relation to teachers and pupils is presented; e.g., a baseline about the actual teaching behavior of all teachers, the pupil perceptions about the teaching of their teachers, the ICT-skills of the pupil and teachers, the mathematics scores and levels of cognitive processing of the pupils. This limitation is especially valid if we look at the studies that focus on the results obtained in the year 2002. The studies that were based on the results of 2003 could build on the results of 2002. As such, a baseline is available for a basic set of research variables in these studies.

Third, the sample sizes used in the studies of 2 (8 teachers and their classrooms) and the studies related to pupils' cognitive processing of chapter 3 and 4 (64 pupils) are small to very small. Consequently, the methods used in the data analysis had to be restricted to non-parametric methods or to methods that required the use of categorical variables (logistic regression). This affected the power of the statistical analyses. Therefore, it was difficult to adopt multivariate analysis techniques. Likewise, another restricted approach was the one followed in chapter 1 when analyzing with descriptive statistics the questionnaire answers. However, this approach helped to create a tentatively baseline about teachers from the Peninsula region that was not available at the time the study was set up.

The measurement approaches adopted in the studies (e.g., video analysis) were too time consuming to be applied to larger numbers of teachers and classes. Even though the use of alternative methods -video analysis- resulted in rich data, the coding of the teachers teaching activities (32 hours of video) and the collaborative tasks of the pupils (128 pupils x 1 hour of video) resulted in a heavy work load and was very time consuming.

Fourth, due to the nature of the quasi-experimental designs, the researchers could not control all the variables that might have affected teacher behavior or pupil learning; e.g., school environment, school ICT policy, parents participation, pupils' perception about learning, teachers' beliefs about learning and teaching, etc. Moreover, certain extraneous variables such as the long strike of teachers that might influence pupils' learning were outside the control of the researchers.

Fifth, other alternative measures to contrast pupil ratings about their perceptions of adoption of social-constructivist principles were not used in studies covered in chapter 2 to chapter 5 e.g., interviews, focus groups, etc. The remarks made about the

potential bias in teacher perceptions, can be repeated here about pupil perceptions. The same can be said about study 2 in chapter 1; no other comparative methods were used to contrast personal ratings or answers of the teachers gathered using questionnaires.

Sixth, due to the limitations previously presented, questions can be raised about the generalizability of the results of the studies. We suggest – in cases were generalization can be put forward – to limit this to the instructional setting and context of the Ecuadorian, the Guayas province or the Peninsula setting.

Finally, the qualitative study presented in chapter 5 also presented specific weaknesses e.g. the number of experts participating in the focus group. Only one meeting was organized; though this meeting lasted 6 hours. A personal bias of the external experts might have affected the findings of this chapter.

Implications of the research findings

The results of this dissertation have theoretical, methodological and practical implications, as well as implications for further research.

First, we think that our results contribute to the progress of research about ICT and its impact on teaching and learning. For example, we found the use of social-constructivist teaching principles and the mindtools are somehow linked to the demonstration of higher levels of cognitive processing in near transfer tasks. At a theoretical level, these results are helpful to explain to a better extent the impact on performance measures in school subjects (e.g. the mathematics scores). The latter was obvious when the results were helpful to reveal that pupils who demonstrated higher mean level of cognitive processing did reach higher mathematics scores. Nonetheless, these relationships could not be analyzed using multivariate analysis due to the shortcomings mentioned in the above section (sample sizes and related constraints). More research is needed since the hypothesis that social-constructivist practices in the classroom foster the achievement of better mathematics scores could not be confirmed. Future studies should refine the theoretical base and look in more detail to the actual relationship between ICT-based teacher training activities, the teaching strategies implemented in the learning activities and the expected process and product outcomes. The cognitive model, presented in this research is only a first step to a more advanced theoretical base. In addition, this theoretical model also incorporates characteristics of teachers and pupils. From a theoretical point of view, there are clear implications when

we focus on teacher and pupil perceptions about teaching and learning. Their interaction effect presents a clear agenda for future research. But – to conclude this subsection about the theoretical implications - the results of the several studies also help to put the social constructivist paradigm in a more realistic perspective. The literature about constructivism reflects a very enthusiastic and optimistic picture of its value for learning and instruction. But, the results of the present research imply that we cannot put forward a ready available empirical base for all the social constructivist assumptions. At least, more research is needed. Current educational practices should therefore be sensible when adopting instructional approaches not yet sufficiently grounded in research.

Second, there are methodological implications of the studies. A key issue is the importance to set up longitudinal research studies. Interesting findings about teachers' teaching behavior and pupil learning aroused when the results of the longitudinal studies were pulled together. The fact that we detected differences in the results between mid term and long term studies (e.g., average adoption of constructivist teaching strategies) is a clear example. Another clear methodological implication is the consideration of interaction variables in studying the impact of ICT-based learning environments. Studies should consider the impact of (previous/continuous) teacher training and control for the actual adoption of the teaching principles pursued by the training. A second type of interaction variables is the characteristics of pupils and teachers. The studies also point at the relevance and importance to include alternative research methods to study outcomes of teaching and learning. Next to the analysis of product outcomes (e.g., mathematics) also processes have to be analyzed (e.g., observation and analysis of actual teaching activities and actual learning processes of pupils). The studies also demonstrated that –although this clearly presents difficulties– research can and should be set up in authentic educational settings.

Third, there are practical implications related to this research and are summarized as follows. Firstly, innovation projects should adopt a long term perspective when studying expected project outcomes. Positive changes and results should only be expected after at least three years in the project. The IEPSE project also demonstrated that setting up scientific research alongside these projects might help to monitor and guide the project. This might foster a more evidence-based orientation towards the adoption of new instructional principles. Secondly, projects should especially foster teacher training before and during the project. Thirdly, ICT-related projects should focus on both ICT-based and non ICT-based activities when pursuing

changes. Fourthly, the teacher training should not only focus on the development of instrumental knowledge and skills in teachers. As revealed by the research results, the training should especially cater for the development of congruent and consistent perceptions and assumptions about learning and teaching. These should be in line with the tools put forward to support the educational changes. Fifthly, educational evaluation should not only focus on the impact of teaching and learning on subject domain knowledge. The impact of ICT-based innovations is also to be evaluated by the teachers in the field of cognitive processing.

The theoretical, methodological and practical implications of the studies also put forward an agenda for future research in this field. We summarize the most important elements of this programme. First, research at a *larger scale* is needed. As stated in the *limitations* section, the measurement approaches have been the limiting factor in the present research. It is therefore crucial to develop and adopt semi automated coding and analysis techniques that will imply a smaller work-load. Setting up the research at a larger scale is also in line with an overall up-scaling of the IEPSE-projects and the need for diffusion as suggested by the experts in the qualitative study. Second, an attempt should be made to set up *experimental* designs, involving sub-samples of teachers and pupils. These studies could help to substantiate and or corroborate to a better extent, the results presented in this thesis.

Third, *qualitative methods* should be incorporated in future research. This is not only considered of value to triangulate the findings of the quantitative studies, but is also helpful to contextualize the findings. As to the former, it is also important to develop qualitative techniques that are helpful to corroborate the results related to the impact on pupil performance.

Adopting this future research agenda might result in research results that can be more easily generalized to other contexts.

General conclusions

The title of this dissertation is *The effect of an ICT-based teacher training programme – based on a social constructivist model- on the teaching and learning activities in primary schools in the Ecuador setting.*

We can conclude overall that the teacher training programme has positively affected the teachers involved in the project. Yet, the pupils of these trained teachers only demonstrated modest to no learning gains.

The IEPSE training programme was analyzed and evaluated at the international and national level and it was found to follow current trends of teacher training based on ICT and teacher training approaches in line with state-of the art trends. We think that the contents and educational approach of the IEPSE training and its effect on teachers might be used as a reference in rural villages of the Guayas province in Ecuador –the province to which the Santa Elena Peninsula belongs. The results of this research can also be used as a catalyst to influence Ecuadorian educational leaders i.e., the need for an updated national reform that explode the advantages of teacher-mediated ICT environments and reflect these benefits in primary education of Ecuador.

A clear attempt was made to consider key problems that were present in previous research. However, due to the limitations previously put forward, future research is needed to be able to generalize our findings. An initial agenda for this future research was presented. This could be done in line with the overall up-scaling of the IEPSE project and the diffusion of its results.