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Self-regulated learning through writing on computers: Consequences for reading comprehension

Anne-Mari Folkesson [1], Lena Swalander [*,1]

Department of Health and Behavioural Sciences, Kalmar University, Stagneliusgatan 14, S-391 82 Kalmar, Sweden

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Abstract

The overall aim for the present study was to analyze the consequences for reading ability among the children of a computer supported self-regulated learning environment in grade two. By means of a quasi-experimental design in a natural setting, an experimental group ($n = 39$) was compared to a control group from a national sample ($n = 3409$) on reading comprehension. The statistical analyses showed that the experimental group achieved better on reading comprehension both as a group ($p < .001$) as well as girls ($p < .001$) and boys ($p < .05$) separately. The proportion of high achievers was higher, and the proportion of low achievers was lower in the experimental group. In order to explain the level of reading comprehension in the experimental group Structural Equation Modelling (SEM) was used. The main explanatory factor for reading comprehension was writing with $\beta = .44$. As a tentative conclusion it was suggested that the extended writing in combination with the self-regulated learning environment can promote reading comprehension in grade two, whereas home literacy had no impact on reading comprehension in this context.

Keywords: Computers; Home literacy; Reading comprehension; Self-concept; Self-regulated learning; Writing

* Corresponding author. Tel.: +46 480 44 6765; fax: +46 480 44 6955.
E-mail address: lena.swalander@hik.se (L. Swalander).
[1] The order of the authors is arbitrary, equal responsibility is assumed.

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1. Introduction

Recent reading research (Martin, Mullis, Gonzales, & Kennedy, 2003) has shown that reading ability in 9–10 year old children has significantly decreased between 1991 and 2001 in only one out of nine countries, namely Sweden. In addition, a current study of 15-year old students has shown a decrease in reading ability in Sweden (Elmeroth, 2005). As early reading ability is crucial for further success in school, it is important to study how reading development in young children can be promoted. According to Jacobson and Lundberg (2000), it has been difficult to relate reading ability to a specific teaching method. Hence, these authors suggested the inclusion of other aspects of reading and assessments as well as a holistic approach. One such aspect might be motivation since Topping and Paul (1999) have found that unmotivated readers seem to put in as much effort in avoiding reading as in actually reading. It is assumed that a study of environments where even unmotivated readers enjoy reading might be of interest. Consequently, we want to go beyond teaching methods, and try to illuminate the understanding of reading development through means of self-regulated learning and self-directed writing activities.

The aim of this study is twofold. In part I, the aim is to explore whether or not reading ability in grade two is positively influenced by a computer supported environment characterized by self-regulated learning, and also to take the gender differences into account. The aim of part II is to explore some of the potential explanations for reading ability in the experimental group.

The literature review is structured in the following way: firstly, research on reading is presented and secondly the research on self-regulated learning in relation to computer use is outlined. The third section deals with writing in relation to computer use. In the fourth and fifth sections, the individual prerequisites in the form of home literacy and self-concept are dealt with. Finally, the research questions and hypotheses are summarized.

1.1. Reading

Reading achievement has previously been found to be substantially predicted by amount of independent reading among elementary school children (e.g., Cipielewski & Stanovich, 1992), where the amount of reading not only is correlated to achievement in a simple association, but could be viewed as the foundation for reading development (Cox & Guthrie, 2001). An explanation for children's frequency and amount of reading can be their capability to use different strategies when reading (Guthrie, Schafer, Wang, & Afflerbach, 1995). A fundamental issue seems to be the use of metacognitive strategies for the understanding of texts (Pressley & Ghatala, 1990) and primary school children have been found to develop metacognitive skills when working together on a computer (Denis & Hubert, 2001). Computer-based reading training has previously been found to be beneficial for both dyslexic and "garden-variety poor readers" (Jimenez, Ortiz, & Rodrigo, 2003). In addition, Wise, Ring, and Olson (2000) showed that computer-based phonological training resulted in improved word reading. In accordance with this, we assumed that the experimental group of the present study would develop the metacognitive skills needed for comprehension by using computers.

Regarding gender differences in reading, the IEA studies conducted in 1970, 1990, and 2001, as well as PISA 2000 and PISA 2003 showed that girls achieved at significantly

higher levels than boys in almost all the participating countries (Elley, 1992; Martin et al., 2003; OECD, 2001, 2004). In this study gender also is included since we would like to investigate if this specific computer supported environment will result in gender differences of a smaller magnitude than previously found.

In the following sections the independent variables used in the present study are discussed starting with the concept of self-regulated learning as related to computer use.

1.2. Self-regulated learning and computer use

Self-regulated learning is a multifaceted set of functions (Boekaerts & Corno, 2005), which in previous research (Zimmerman, 1994) has been referred to as "... the degree that individuals are metacognitively, motivationally, and behaviourally active participants in their own learning process" (p. 3). Thus, a person who has developed self-regulated learning is able to self-direct the process by which the mental abilities are transformed into academic skills (Zimmerman, 2001, 2002).

In self-regulated learning the motive for learning is important and self-regulated learners usually are intrinsically motivated or self-motivated (Zimmerman, 1994). Intrinsic motivation has been found to correlate with interest, enjoyment, felt competence, and positive coping (Ryan & Deci, 2000; Ryan, Kuhl, & Deci, 1997). There have been suggestions that modern information technology can increase both motivation and self-esteem and that the advantages of computer use are numerous: e.g., the child gets immediate feedback, the computers are not judgemental yet predictable, they can provide overlearning and maybe most importantly, they provide new motivation (Fawcett & Lynch, 2000; Hall, Hughes, & Filbert, 2000; Riis, 1991).

Some positive overall outcomes of computer use for the learning environment have also been reported e.g., the children become more helpful and friendlier (Riis, 1991). Furthermore, collaboration and engagement are reported to increase dramatically when writing together on the computer as compared to a similar paper-and-pencil task (Alexandersson, Linderoth, & Lindö, 2000; Helleve, 2003). Writing on computers allowed the students to reflect on their texts as it was easy to make changes, and therefore they spent more time on-task (Somekh, 1991). Alexandersson et al. (2000) have observed that linguistic awareness was enhanced when the children could read their text on the screen as they were writing. This inspired the children to elaborate the text and experiment with spelling, especially when sitting together with peers. This is in accordance with Boekaerts and Corno (2005), who reported that collaborative learning sustains self-regulated learning.

Traditionally, in primary school classrooms there is a tendency for boys to experience a conflict between the standards for the male sex-role and the student's role as defined by the feminine environment that promotes docility and compliance. In these classrooms boys are more prone to stress, are more dissatisfied with school, and feel more alienated (Brutsaert & Bracke, 1994). In line with this, Ferguson and Fraser (1998) found that class satisfaction improved for boys and deteriorated for girls when transferring from primary to secondary school, since primary school classrooms promote more feminine values, whereas in secondary school the values are less feminized.

In line with the research presented above, it is assumed that a self-regulated learning environment, with a high degree of collaborative computer use as well as production of own material, will promote reading achievement. In the next section writing, as another explanatory factor for reading achievement, will be discussed.

1.3. Writing

Since writing, as compared to reading, makes the child a more active participant in learning, Chomsky (1981) claimed that learning to write before learning to read would stimulate language awareness. With reference to Chomsky (1981), Trageton (2003, 2005) suggested that *children* learn to read while writing and that producing own texts on the computer is an easier way to reading proficiency than through reading text books. However, this was not tested empirically. The effect of writing on reading has been studied empirically through early self-directed writing and spontaneous writing attempts (Frost, 2001). As an overall result, this study found that early spontaneous writing and phonemic writing, i.e., writing before knowing the spelling rules, significantly predicted later reading and correct spelling. The author stressed that early reading is enhanced by word production and early phonemic writing (Frost, 2001). In line with this, Jenkins, Johnson, and Hileman (2004) concluded that writing ability was an important factor when explaining reading ability, since writing includes frequent reading and rereading during the writing process.

Some experimental studies have tried to find different effects of computer writing. In a case study, Zhang (2000) concluded that computer writing was liberating the students' cognitive resources so that they could concentrate on ideas instead of concentrating on the technicalities of writing. A large scale experiment conducted by Trageton (2003) showed that the students who started to write on computers in grade one were achieving better in grade three both on handwriting and on text quality. Computer writing was typically favourable for boys. Another case study of writing in a self-regulated setting showed that the experimental group had better results on attitude and performance measures, as well as on concentration and persistence (Sovik, Heggberget, & Samuelstuen, 1997). However, the authors stressed that the results were obtained in a laboratory setting and that they also need to be replicated in a natural setting.

The research review on writing presented above implies that extended writing is likely to improve reading achievement, and that this might contribute to the explanation of reading ability. Other explanations to reading ability are the individual prerequisites of home literacy and self-concept and they will be dealt with in the following two sections.

1.4. Home literacy

Many studies have reported relationships between home literacy, emergent literacy and early reading acquisition. Such relationships now seem to be well established (e.g., de Jong & Leseman, 2001; Snow, Burns, & Griffin, 1998; Storch & Whitehurst, 2001). According to Sonnenschein and Munsterman (2002), storybook reading is a regular practice in middle-income families and not so regular in low-income families but they also state that the within group variability is high. This is in concordance with Adams (1990), who estimated that a typical American middle class child has spent about 1000–1700 h of storybook reading between the ages of six weeks to 6 years, as compared to children from low-income families who experienced an average of 25 h. Furthermore, international research indicates that the single most important predictor of reading ability is number of books at home (Elley, 1992).

1.5. Self-concept

Many researchers involved in developmental psychology and education consider self-concept to have a close relation to academic achievement (e.g. Byrne, 1996; Harter, 1998, 1999; Marsh, 1993). Despite this, not much research has been conducted on young children. One problem is that children in the early school years often rank themselves very high in reading ability without there being any correlation with actual performance (Eccles, Wigfield, & Schiefele, 1998). As for gender differences, Wigfield, Eccles, and Pintrich (1996) argued that any generalization is problematic, due to the confounding impact of ethnicity and SES. They, however, noted some trends, namely that, boys to a greater extent than girls are "self-congratulatory" when asked about self-efficacy whereas girls tend to be more modest. Partly in line with this, Pintrich and Schunk (2002) reported inconsistent findings of gender differences in young children. Some studies have not found any gender differences before ninth grade and some have found differences at earlier age. Hence, it was suggested that the nature of these differences is not yet clearly known (see Pintrich & Schunk, 2002).

1.6. Research questions and hypotheses

As a consequence of the research discussed above, our hypotheses for part I of the present study are: (a) The students of the experimental group, in a computer supported self-regulated learning environment with extended writing and production of own material, will show better reading ability than those of a control group from a national sample, (b) The gender differences in the experimental group will be of a smaller magnitude compared with the national sample. The hypotheses for part II are that self-concept, as well as home literacy and gender will contribute to the explanation of reading comprehension and word decoding. Furthermore, in this context we will explore the impact of the extended writing and production of own material on reading ability.

2. Method

2.1. Participants

Initially the experimental group consisted of 42 children from two different but closely cooperating groups in grade two. The natural setting for the experimental group was a small Swedish compulsory school in a small town. The SES can be considered to be of low and medium level compared to the control group (further described below). Two children with special needs were excluded from the experimental group since they did not participate in the reading investigation. One out-lier, a newly immigrated child, was also excluded from the analyses. Thus, the final group-size was 39. The ages ranged from 8 to 9 with minimum = 8 years 4 months and maximum = 9 years 3 months; $M = 8$ years 10 months, SD = .3 (3.6 months). Twenty-seven children had Swedish as mother tongue (69%) and 12 (31%) of the students had a different mother tongue than Swedish. There were 22 girls (56%) and 17 boys (44%).

The control group consisted of a representative sample of 3475 students who participated in the 1995 National Assessment of reading ability. No other national evaluation has been carried out in grade two since then, why this was the only large control group

available. No records of out-liers were reported (Taube & Skarlind, 1997). There were 1720 girls (49.5%) and 1755 boys (50.5%). There were 371 (10.9%) students with different mother tongue than Swedish.

2.2. Setting

In this school, two teachers in a project had developed computer use as a pedagogical tool. The project has been evaluated as a good example of a well developed learning environment, where there were many opportunities for self-regulated learning (Folkesson, 2004). The teachers' aims were to let the students take on more responsibility and to use open-ended software, where the children could express themselves in their own language. The teachers specifically avoided training programs. According to the Swedish National assessment of quality of the reading and writing processes (Skolverket, 1998), self-regulated learning environments were very unusual for the early reading education in primary school.

The classrooms of the two teachers were situated close to each other on the same floor, where there also were a library and a computer room. All together they had 20 computers, of which ten were located in the computer room and five in each of the two classrooms. The classroom doors were often open and the teachers cooperated closely. All the children were free to work in any room on the whole floor and to collaborate with peers of their own choice. In the classrooms, the desks were sometimes put together in small groups and sometimes put in a U-shape. The five computers in each classroom were put in a row on one side of the room. There were only short periods of "chalk-and-talk", mostly of practical and social character in the morning, before and after lunch, and at the end of the day. Thematic work was introduced to the whole class by the teachers and now and then the students presented their work in front of the group.

Teaching was normally carried out as conversations related to the students' own production. During the whole day both children and teachers initiated talk like an everyday conversation among equals; i.e., there were no traditional teacher directed dialogues where the student was to provide a correct answer. The work was characterized by the children's own production, authentic writing, children's discussion of their productions with each other, thematic work, participation, and involvement. The teachers avoided the use of ready made materials and the children were not to reproduce texts but to write everything in their own words (Folkesson, 2004). In conclusion, this setting could be referred to as a highly self-regulated learning environment.

The teachers described their pedagogical ideas by stating that they wanted "everyone to find his or her own driving force". The computers were introduced in grade one by letting the children investigate colours and pictures in the Kid Pix software. Thereafter, they started to use MS Power Point, since this software, compared to Kid Pix, was less complicated to use for creating tales and stories in logical sequences. The ability to organize a logical story was considered to be an important pre-reading activity. The children were taught how to move their own drawings from Kid Pix into a slide show in the MS Power Point software. They soon started to write words, sentences and short texts, thereby learning to use MS Word software by practice. Some children learned quickly, some needed more time to learn, and they soon took the initiative to learn from each other. The teachers showed all the options of MS Word Art and the effect of different layouts in order to encourage the children to find the layout most suitable for certain content. The children

were also suggested to consider the readability of the text. Furthermore, the children were taught to use a scanner and a digital camera; the aim was to use pictures as a stimulus when writing tales, stories, and other texts. In this way the children were not limited to use ready-made pictures.

During the day, the children chose from tasks listed on the whiteboard. They worked in their own pace and there were no rules that regulated the children's collaboration with other students. The teachers moved about in the classrooms and in the computer room helping and supporting the children with comments on language and spelling as well as giving technical help when needed. Sometimes the children waited to get help from their teacher and sometimes they helped each other. Everything they produced was sorted into folders on a server with a folder for every child, labelled with his or her name. The children had their own passwords, and only the teachers had access to all the folders. A data summary from the participant observations is presented below.

2.2.1. A typical day in class

After welcoming small talk, the teacher gives the children information about today's events. On the whiteboard there is a list of tasks from which the children can choose. Some of these tasks (1–7) are compulsory and some are optional (without numbers): "(1) Math p. 58–61, (2) Diary, (3) "Research", (4) Theatre picture, (5) Manuscript + text (slide show), (6) Kid-Pix to Power Point + sound, (7) Book review, Hand writing, Reading, Math game, Lexia, Extra slide show—Power Point" (our translation).

The teacher explains the tasks and checks that everybody knows what to do, and then she tells the children to "please get started". All the children calmly start fetching a diversity of materials, while talking quietly. When they start talking louder, they are asked to help each other by lowering their voices, the teacher reminds them that they themselves have been complaining when it is too noisy; and right away the voices are much lower.

After a while, most of the children have started to work on different tasks using the computers. Tina is drawing pictures in Kid-Pix to make a "Picture tale". When she has finished her pictures she puts them in her folder on the server and then she moves them to a Power Point slide show. She also puts in a recorded speech so the teachers and the peers can listen to her tale. Several other children are working on the same task. Most children first write the text, and then they make a tape-recording of the text.

Maria uses Kid Pix to "scribble" with ready made pictures, she alters the shape and appearance of the pictures in different ways, seemingly to test the options of the program. Finally, she finds a picture of Ariel (the little mermaid). She wants to use a reversed copy together with the original picture to illustrate a tale about two friends; however, she does not know how to reverse a picture technically. Immediately, two classmates come to help; after some trial and error, together they solve the problem and Maria can continue.

Tom is doing "research" on Titanic, inspired from the yesterday's presentation made by a peer. He is drawing the ship in Paint brush. Many peers get interested and they start an animated and constructive conversation about the size of the iceberg and what it looked like. At the same time, Tom redraws the iceberg several times along with the outlined ideas.

At a different computer Isac is sitting next to Tony. Isac is wearing ear phones listening to Tony's tale. He seems really interested in his classmate's work. Close to them, John is working alone on another computer. He is creating a tale in Kid Pix at the same time as he is making the pictures. After that, he writes the text and thereafter makes a tape-recording.

The teacher gives comments on language and spelling as well as emotional support and assists with the tape recording.

Glenn is working on the optional extra slide show in Power Point. He does not create a traditional tale, but a story about himself. He uses both written sentences and pictures from a folder on the server. In this folder, the teachers have put photos of the children from various occasions, activities and excursions and also diverse pictures from Clip Art.

Now the teachers remind the children that it is time for recess but many children do not seem to care, and they continue their work. After the recess, half the group is supposed to go to a leisure time centre for one hour but Sophie wants to stay in class to help Anna (who is a newcomer) with her research, so that Anna will not be left too much behind. When the other half of the group is gathered again after recess, the teacher once again goes through the list of tasks on the board and all the children are asked to tell what they have planned to work on. The teacher is checking up on everyone to make sure that all children have something to do before they can get started.

Peter tells his teacher that he has been working on his kangaroo research at home. His parents have helped him to search the Internet and he wants to show the teacher some pictures. He has also found a story written by a sixth grader in another town and he has underlined parts from her text, which he wanted to use in his research.

Jimmy asks for help about a technical matter, the teacher says "I don't know but let's try and see". A peer says that he knows, "Ok", says the teacher "you do it". She turns to two other children and together with them she discusses how to technically organize the texts and the pictures in their tale. Then Lisa asks for help to save her file.

The teacher is helping Maria to numerate her slide show, something went wrong and neither the teacher nor Maria can solve that problem. "I think Sophie knows", Monika says and goes to find her. Sophie comes, solves the problem with ease and returns directly to her own work. The teacher and Maria continue the work and now it is time to elaborate the text. Maria is instructed to make full stop after a sentence, to use capitals, and to use a variation of words, not only "and ... and". This takes some time so two boys who need help have to wait. "All right, we can make a slide show together for a while", they say with a smile and leave.

Now Jennie comes asking the teacher for technical help. Since the teacher is not finished with Maria, she asks John to help. Without further do he leaves his mate in the middle of their work to assist Jennie.

Carl, a boy with dyslexia, slowly tries to put together words to describe a picture. He tries by using phonemic writing but after a long while he deletes everything and asks for help.

Glenn, who was making a story about himself, is still concentrated on this work. He is working a lot with the layout. He seems to like watching pictures of his classmates "flying" into the slides in a variety of ways. During a conversation with another boy, he finds a new theme in the story about himself, called "my friends". Suddenly the teacher says: "Oops, we have forgotten about time...it is lunch hour."

After lunch, the teachers gather the children, and they all sit in their own classroom for a while talking about what happened during lunch break and then the teachers read from a story book. After that, the children go on with their chosen tasks for one more hour.

Some children are now doing Math tasks in one classroom. They have trouble understanding the task so they go to the teacher and ask her to explain. In the next moment, Sandra and Frida need help to choose a task since no computer was available for the

moment. When the teacher tries to help them choose a task her colleague is coming from the other classroom to discuss something. At the same time, two children approach to take a picture with a digital camera.

Carl, the dyslectic boy, has not written very much. The teacher tries to help; on a paper she writes a sentence that suits the picture so that he can copy the sentence to his document on the computer. This seems to be necessary scaffolding for him.

Peter is working on a slide show, where he is writing about his leisure time activities. Martin has found a flower on the school yard. The teacher takes a photo with the digital camera, and puts it in the photo folder, so that Martin can move the picture to his own folder and write about his flower.

Henry is writing an e-mail to a friend who is ill in bed, telling him what they have done in school. Simon starts working on a task intended to teach the children to use the table function. He is making an investigation among his classmates about their favourite sports and will present the results in a table. At the same time, other children are moving about asking about other favourite things for their investigations. The work on the table task results in many errors, and Simon deletes and restarts many times. But this does not seem to annoy him.

In the end of the school day the children become less concentrated and when the teacher gathers them to say good-bye many of them seem tired and eager to run off and play whereas others stay and talk to the teacher for a while.

2.3. Materials

As the dependent variables, two *reading tests* (reading comprehension and word decoding) were used. As independent variables, several materials were employed namely a *questionnaire*, *children's writings* and *children's drawings*.

2.3.1. Reading tests

The experimental group was subjected to the same reading test that was applied in year two in the National Assessment directed from the National Board of Education in 1995 (Taube & Skarlind, 1997). Two tests were given to all the students: "Student pictures" and "Word chain test" (Taube & Skarlind, 1997). The correlation between the two reading test was $r = .55$, $p < .01$ but these two reading tests are measuring two different aspects of reading achievement, reading comprehension and word decoding, hence they are used separately.

The test "Student pictures" includes 40 tasks. This test is supposed to measure the students' skills in quick word recognition and uncomplicated reading comprehension. Each task consists of one sentence and four pictures. The students were instructed to indicate the picture illustrating the sentence. The differences between the four pictures are intended to be sufficiently obvious for the students to choose the right one, if they have understood the sentence. The time for this test was 10 min. An example of this reading test is provided in Fig. 1.

The "Word chains test" consists of 72 word chains and aims to measure word decoding skill. This test is considered to require a rather low proficiency of reading comprehension. A word chain is a sequence of two, three or four words written as one word, e.g. boygomeet. The students are asked to indicate the different words with a slash; in the example boy/go/meet. For this test the time was 5 min.

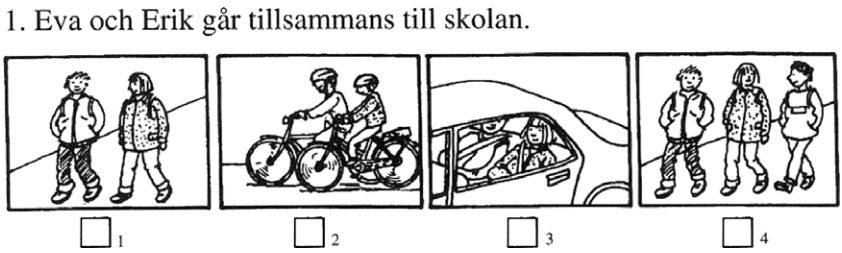

Fig. 1. Example from the reading test "Student Pictures". The english translation is "Eva and Erik are walking together to school" (our translation). Copyright Skolverket. Reprinted with permission.

2.3.2. Questionnaire

The children in the experimental group answered the same questionnaire used in the control group. Some items were used to construct the latent variable *home literacy*. These questions concerned the number of books for grown-ups (NBOOKS) as well as for children (CHBOOKS) in the family. Additionally, some questions indicated how often the parent had been reading to the child before entering school (FAMILYRE), and how often the child read books (RBOOKS) and comics (RCOMICS) when they were out of school.

2.3.3. Children's drawings

The variable *self-concept* was constructed of four different measures from the children's drawings of themselves and the teacher in the classroom. These measures have previously been used in a study of social scaling in different cultures with respect to child centeredness of the particular culture (Aronsson & Andersson, 1996). The underlying assumption is that human figure drawings reflect the child's attitude towards himself or herself. The child is involved in a specific social situation in school and this will appear in the children's drawings. Hence, a drawing of the child in the school environment is assumed to be a projection of the child's self-concept as situated in the specific social situation (Aronsson & Andersson, 1996). The children's drawings have also been analyzed in a separate study of the actual school, revealing that the students in this sample show a comparatively high degree of child centeredness (Folkesson, 2003). The measures, in accordance with Aronsson and Andersson (1996), were: (a) the relative size of the student in relation to the teacher (SIZE); (b) the relative degree of detailing of the child in relation to the teacher on a three grade scale (DETAIL); (c) whether or not the child is in a central position in the picture (CENTRAL), and (d) whether or not the child is depicted in a student–teacher dyad (DYAD). The latter two variables are dichotomous. These four measures were used as separate indicators of the latent variable self-concept.

2.3.4. Children's writing

The variable *writing* was constructed from three authentic school tasks. One task was the children's narrative about an incident when the computers were stolen from their school, another task was a teacher conducted evaluation where the students were asked to rank order and write about what kind of school work they liked the most. The third writing task was to write an essay about "An ordinary day in school". From these three writing tasks both quantitative and qualitative measures were used. The quantitative measures were number of words in the narrative task (NARRWORD), number of words in the evaluation task (EVALWORD), as well as in the essay (ESSWORD). The qualitative measures,

explanations in the narrative task (NARREXP) and explanations in the evaluation task (EVALEXP), were quantified as number of explanations in each of these two writing task.

2.4. Procedure

A quasi-experimental design, with the experimental group coming from a natural setting and the control group coming from a national sample, was applied. All the data were collected by the teachers in ordinary lessons at different times but all within five months in grade two. As for the *writing tasks*, the evaluation was given to the students at the end of the fall semester in December, and the narrative was written in the beginning of the spring semester in January. The essay was written in the fall of grade three, with seven children occasionally absent. For the *reading test* and *the questionnaire* the conditions corresponded to those of the National Evaluation 1995, which also took place in April.

The children's drawings were made in April as well. The instruction to the children was: ''Draw yourself and your teacher when you work in school. If you want, you can draw your classmates and as much as you wish of the room. Try to think of a work you are doing and what it looks like when you work.'' When the students were finished, they were asked to indicate themselves and the teacher as described by Aronsson and Andersson (1996).

2.5. Data analyses

The data analyses for part I were made with single-sample *t*-test as well as with MANOVA. For the data analysis of part II, maximum-likelihood estimation in Amos 5 Structural Equation Modelling software (model specification through a path diagram interface) was used. The aim was to explore the effect of the latent as well as the manifest variables on reading achievement. According to Hoyle and Panter (1995), there is a growing body of research indicating that maximum likelihood performs well under less than perfect analytical conditions and thus, has been found to be very robust. To judge the fit of the model, multiple fit indices were used. For the initial findings we used the χ^2 which tests the lack of fit resulting from over-identifying restrictions placed on a model (Hoyle & Panter, 1995). The smaller the χ^2 is, the better the fit of the model. The Root Mean Square Error of Approximation (RMSEA) was used to test the fit of a single model. A RMSEA of about .05 or below indicates a close fit of the model and a value between .05 and .08 would indicate a reasonable error of approximation (Browne & Cudeck, 1993). RMSEA is a population-based index, and is therefore quite insensitive to sample size (Loehlin, 2004). As incremental fit indices we used the Comparative fit index (CFI), which indexes the relative reduction of lack of fit as estimated by the noncentral $\chi^2$of a target model versus a baseline model (Hoyle & Panter, 1995). According to Hoyle and Panter (1995), the value .90 stands as an agreed-upon cut-off for overall fit indices to suggest an adequate fit and .95 suggests good fit.

3. Results

3.1. Differences in reading ability between the experimental and the control group

To examine the differences in reading comprehension and word decoding between the experimental group and the control group, single sample *t*-tests were used. Means and standard deviations for the experimental and the control group are reported in Table 1.

Table 1
Means and standard deviations in reading comprehension and word decoding. Cohen's *d* for the significant differences concerning reading comprehension

	Reading comprehension					Word decoding			
	Exp. group $n = 39$		Control group $n = 3409$			Exp. group $n = 39$		Control group $n = 3408$	
	M	SD	*M*	SD	Cohen's *d*	*M*	SD	*M*	SD
Total	36.41	5.24	31.8	9.5	.6	28.77	15.72	24.6	15.8
Girls (separately)	37.68	3.43	33.1	8.6	.7	32.64	15.96	27.4	16.1
Boys (separately)	34.76	6.69	30.6	10.2	.5	23.76	14.34	21.8	15.0

The first test showed that the experimental group did not come from a population with $\mu = 31.8$ on reading comprehension $t(38) = 5.38$, $p < .001$ with Cohen's *d* of .6. The second test, including only girls, again showed better reading comprehension result for the experimental group $t(21) = 6.24$, $p < .001$ with a Cohen's *d* of .7. The third test concerned only the boys and again the results were in favour of the experimental group $t(16) = 2.57$, $p < .05$ and Cohen's *d* was .5. No significant differences on word decoding were found in any of the three corresponding tests.

In the experimental group, the proportion of high achievers was higher, and the proportion of low achievers was lower as compared with the control group. In the control group, more than half the sample (51%) answered at least 37 questions correctly on the "Student Pictures" test (Taube & Skarlind, 1997). A considerably higher relative frequency of students (74.4%) in the experimental group answered at least 37 of the 40 questions correctly. It is also worth noting that the relative frequency of low achievers (<50% correct answers on the "Student Pictures" test), was much lower in the experimental group (2.6%, i.e., one student) than in the control group (17%).

Since we wanted to control for the impact of gender, a MANOVA, with gender as the independent variable, was conducted. The dependent variables were reading comprehension, word decoding and the four measures of the self-concept instrument. The MANOVA showed no significant differences between boys' and girls' reading comprehension and word decoding in the experimental group. The MANOVA however showed a significant difference in one of the four self-concept instruments, namely the dyad, where boys more often draw themselves in a dyad with the teacher $F(1, 38) = 4.27$, $p < .05$.

3.2. Explanation of reading comprehension in the experimental group

In order to explore the potential explanations for reading comprehension in the experimental group, a SEM was constructed. A two-step approach was used to test the hypothesized model. The first step was to test the measurement models, i.e., to conduct confirmatory factor analyses for the latent variables, home literacy, self-concept, and writing.

For the first latent variable, *home literacy*, two different models were tested. The first model consisted of the measured variables: reading of books, number of books, number of children's books, and family reading. For the second model reading of comics was included. The reason for this was that this measurement was positively correlated ($p < .05$) with reading comprehension for boys. Both models were good as judged by

Table 2
Model comparisons for measurement models and structural equation models

Model comparison	χ^2		df		χ^2 diff	df diff	p	RMSEA (LO90–HI90)	
	1st	2nd	1st	2nd				1st	2nd
Home literacy	.89	1.79	2	5	.90	3	n.s	0 (0–.25)	0 (0–.11)
Full structural model	137.58	98.78	99	85	38.8	14	<.01	.1 (.06–.14)	.07 (0–.12)

Note. (LO90–HI90) = confidence interval for RMSEA.

the χ^2, and none was significantly better than the other (see Table 2). The RMSEA was lower for the second model why this model was chosen over the first.

The second latent variable to be tested was *self-concept*. As indicators in this model, the measurements for size, detail, centrality, and dyad were used. The model proved excellent fit to the data as judged from both χ^2 and the fit indices.

The third latent variable, *writing*, which consisted of narrative word, narrative explanation, evaluation word, evaluation explanation, and essay word, proved to be good as judged by both the χ^2 and RMSEA.

The next step was to test the structural equation model, where the latent variable models were connected to the endogenous variable reading comprehension. Two different models were tested and both models are nested. In model 1, apart from the three latent variables, the manifest variable *gender* was included as an exogenous variable connected to reading comprehension. The different judgements of fit revealed that this was not a good model (see Table 2). Since the standardized regression coefficient for gender was not significant, it was removed for model 2. As judged by the χ^2 difference test, this was a significantly better model, and as judged by the other measures of fit it was an applicable model (see Table 2). The judgements of fit for all used measurement models, as well as the final structural equation model, are reported in Table 3, and the full structural equation model with standardized regression coefficients is presented in Fig. 2.

In this model, 36% of the variation in reading comprehension is explained by the variables included in the model. The direct effects, significant for reading comprehension, were writing and self-concept with a positive effect from writing with a β value of .44. The effect from self-concept was negative with a β value of $-.30$. The path from home literacy was not significant and therefore the parameter estimate is hidden in the figure, but the path is still kept for theoretical reasons.

To sum up, the results show that the experimental group from the computer supported learning environment had significantly better reading comprehension than the control group. It can also be concluded that the individual prerequisites can not explain reading comprehension in this group, and that writing, which is a result of the specific environment, is the strongest explanatory factor.

Table 3
Fit indices of measurement models and final model

Model	χ^2	df	p	CFI	RMSEA (LO90–HI90)
Measurement model for home literacy	1.79	5	.88	1	0 (0–.11)
Measurement model for self-concept	.00	2	1	1	0 (0–0)
Measurement model for writing	1.53	5	.91	1	0 (0–.09)
Final structural equation model	98.78	85	.15	.86	.07 (0–.12)

Note. CFI = Comparative fit index, RMSEA = Root mean square error of approximation, (LO90–HI90) = confidence interval for RMSEA.

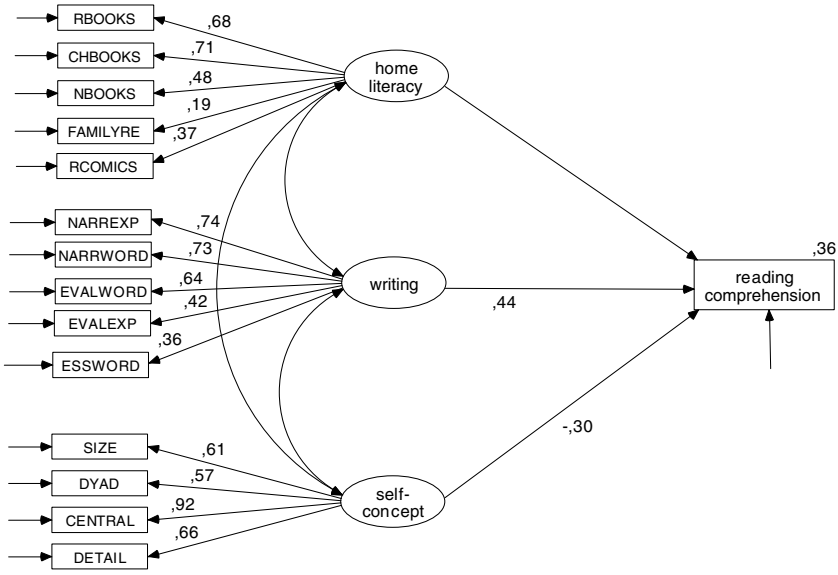

Fig. 2. Structural equation model for reading ability in experimental group. RBOOKS = voluntary reading books; CHBOOKS = number of books for children; NBOOKS = number of books for grown-ups; FAMILYRE = parents reading aloud before school; RCOMICS = voluntary reading comics; NARREXP = number of explanations in the narrative; NARRWORD = number of words in the narrative; EVALWORD = number of words in the evaluation; EVALEXP = number of explanations in the evaluation; ESSWORD = number of words in essay; SIZE = relative size of pupil versus teacher; DYAD = pupil and teacher in a dyad; CENTRAL = the pupil in a central position in the classroom; DETAIL = relative degree of detail in the pupil's face versus teacher's face.

4. Discussion

The aim of part I was to explore if reading ability was positively influenced by a computer supported environment characterized by self-regulated learning, and also to take the gender differences into account. In part II, the aim was to explore some of the potential explanations for reading ability in the experimental group. Even though the sample of the experimental group is very small and there was a big sample size difference between the experimental and the control group, some tentative and cautious inferences about the consequences for reading comprehension can be made.

The discussion is structured as follows: first we discuss the differences in reading comprehension between the experimental group and the control group and then we discuss the SEM and its implication for reading comprehension in the experimental group. Next the limitations of the present study will be outlined and finally some conclusions are drawn.

4.1. Experimental group versus control group

The favourable results for the experimental group concerning reading comprehension, and also the lack of gender differences, can be given at least two potential explanations related to the data: *the extended computer use* and *the learning environment*. Although these issues can not be fully separated, they will be discussed one by one.

4.1.1. Extended computer use

One explanation for the positive reading results in the experimental group is the motivating power of computers, which previously has been shown in both early and more recent studies (e.g., Fawcett & Lynch, 2000; Hall et al., 2000; Riis, 1991). The motivational aspect can be crucial since avoiding reading is an energy consuming strategy for unmotivated readers (Topping & Paul, 1999).

Another explanation is that the children were reading more than children in a traditional classroom due to the extended computer use. Computer written texts are easier to read since the letters and words are clear and distinct, and therefore the children simply read more. According to reading research in the early grades (e.g. Cipielewski & Stanovich, 1992), the amount of independent reading can considerably explain reading achievement for elementary school children. A further explanation is that it might be advantageous for the children in the experimental group to practice reading in a meaning directed way like producing and editing their own texts together with peers. Such reading can be related to the theories of self-regulated learning where students are engaged actively and constructively in a process of meaning generation including adaptation of thoughts, feelings, and actions to facilitate learning and motivation (e.g., Boekaerts & Corno, 2005).

Computer writing is probably especially advantageous for boys, since hand writing often is harder for them due to undeveloped fine-motor skills in the early years (Tanner, 1990). As shown by Trageton (2003), boys performed better on hand writing as well as on the content when writing was introduced with computers as writing tool and hand writing was postponed until grade three. Thus, the computer seems to be a helpful tool, still not common in primary school classrooms. In previous research (Alexandersson et al., 2000), it is argued that primary school teachers are uncertain of how to use computers for young children. Consequently, it is not the mere access to computers that is important, rather it is a question about how and in what learning environment they are used.

4.1.2. Learning environment

As previously shown, children sitting together in front of a screen are stimulated to externalize their thinking and to get a shared understanding (Boekaerts & Corno, 2005; Denis & Hubert, 2001; Kusunoki, Sugimoto, & Hashizume, 2002). Hence, the children can be expected to develop their ability to explain. These results fall well in line with classroom observations in this setting (Folkesson, 2004), where the children were found to spend a lot of time discussing their work (see the Method section for a description of the setting). This can be compared to traditional classrooms where children are silently working in textbooks on their own (e.g., Skolverket, 1998).

Again, especially boys may profit from the self-regulated learning environment. In this setting the children were free to move about and choose where and with whom to work without asking for permission. A study by Brutsaert and Bracke (1994) indicated that boys usually are more stressed and less likely to be satisfied with school in a feminized primary school setting. Research on gender differences in school has shown that boys are often in opposition to female values common to classrooms in primary school (Einarsson & Hultman, 1984). This may reflect that the western male sex-role implies independence and activity, which is more compatible with self-regulation than the traditional feminized environment where docility and submissiveness are requested (Brutsaert & Bracke, 1994).

Both boys and girls in the experimental group read significantly better than those in the control group, indicating that computer assisted self-regulated environment is valuable for

both boys and girls. This result is, of course, positive but the implications need to be problemized. On the one hand, this learning environment may reinforce the boys' domination of the classroom, and on the other hand, it may also liberate girls from being submissive and docile. This is an open question that needs to be addressed empirically.

4.2. SEM and its implications for reading comprehension

In order to explain the positive result for the experimental group a SEM was constructed. In the following section the impact of the latent variables on reading comprehension in the experimental group, is discussed.

The explanatory value of writing was comparatively high in the SEM, especially when considering the small sample. The impact of writing was in fact found to be the strongest single explanatory factor for reading comprehension. Chomsky (1981) and Trageton (2005) put forward theoretical explanations to why writing would be easier than reading for small children, namely that writing is a concrete activity as opposed to reading which is an abstract activity. Consequently, writing comes before reading and reading skill develops automatically from writing. Moreover, as reported by Frost (2001), word production and early phonemic writing are important for reading development. In the reading and writing practice of the experimental group the students frequently used phonemic writing on the computers.

The conclusions regarding the impact of writing should be interpreted cautiously since it is difficult to separate writing from the specific learning environment. For future reading studies, it would be interesting to develop an analysis instrument for written text quality for grade two like the Washington assessment of student learning which Jenkins et al. (2004) have used for grade four.

The individual prerequisites in the form of home literacy might have been compensated for in the learning environment of the experimental group. As previously shown (e.g., de Jong & Leseman, 2001; Leseman & de Jong, 1998; Snow et al., 1998), the opportunity to interact with literacy in different forms influence the development of literacy positively. However, the learning environment of the experimental group could have a compensatory function for children whose parents give few or no opportunities for literacy developing activities. If children rarely see their parents read or write, they might not feel comfortable with books, papers, and pencils. Thus, the computer is a medium that children with low SES background, as many in the experimental group, may benefit from. This kind of working practices has previously been found especially favourable for low achievers who gained from both peer explanations and peer modelling of appropriate work habits (Boekaerts & Corno, 2005). Moreover, a lot of unintentional reading when using the computer can be seen as a more pragmatic way to develop reading literacy. If this pragmatic way of developing reading comprehension is favourable for children with a low degree of home literacy, this could be a part of the explanation for the positive results of the experimental group compared to the control group, where home literacy showed the expected correlation with reading achievement. The conclusion that "home, language, and emergent literacy are important for later reading achievement" (Storch & Whitehurst, 2001, p. 64) can of course not be contradicted by a single study. However, a self-regulated learning environment with computer supported extended writing might be able to counterbalance the impact of home literacy.

The hypothesized impact of self-concept was not possible to establish with the chosen measures. This will be further discussed in the next section.

4.3. Limitations

A classical problem when studying an innovative project is the Hawthorne effect, where the mere interest and attention of the researchers, as well as the teachers, will increase achievement. On the other hand, the advantage of using a natural sample is that the ethical problem, of some students missing out on positive treatment, is solved.

The influence of the learning environment is a complex matter, which also is a methodological problem. In the present study the learning environment is used as the context in which the study was conducted and not as a defined variable. The combination of extended writing in the experimental group and the special learning environment with focus on self-regulated learning can not be fully separated in a natural setting like the present. To facilitate more valid conclusions it would be necessary to separate the impact of these two factors in order to study the impact of each one in a controlled experiment. It would also be valuable to study the teacher impact, which was not possible with this natural setting design.

The experimental group, where the SEM was applied, had a very small sample. It is not optimal to have sample sizes <100 and according to Loehlin (2004) the statistical claims should be very modest in those cases since the statistical properties depend on large samples. Moreover, in these cases it can be ambiguous to use the fit indices as well as χ^2 since the estimations will be underestimated (too conservative), except for RMSEA which is rather insensitive to sample size. West, Finch, and Curran (1995) recommend using the CFI when having a smaller sample than 200 since the estimations with the CFI only are underestimated with 3–4%. Concerning the χ^2, in very small samples it might be too low which would imply a good model despite the model *not* fitting the data. The gain of conducting a SEM is that the holistic approach makes it possible to get the full picture immediately and hence, it is a more comprehensive and flexible than any other standard approach (ANOVA or regression analysis). Another gain is that not so many calculations are needed and therefore SEM also implies not capitalizing on chance. As for capitalizing on chance, it could be argued that a more restricted alpha-level should have been applied. Nevertheless, since the sample size of the experimental group is rather small and the approach is exploratory we find it justified to have the alpha-level set at .05. However, these limitations must be kept in mind when interpreting the results of the current study.

The lack of influence of home literacy might indicate reliability problems. The children are so young that their answers concerning the issues of home literacy may have low reliability. On the other hand, these questions are previously tested and showed the expected results in the control group (Taube & Skarlind, 1997). It would, however, be valuable to further develop measurements for home literacy in young children.

Finally, the projective self-concept measurement used in this study was intended to measure a social dimension of global self-concept in a classroom environment and not a "traditional" academic self-concept (Byrne, 1996; Marsh & Hattie, 1996). The drawings were presumably not suitable for measuring self-concept but rather for measuring child-centeredness as suggested by Aronsson and Andersson (1996). Nonetheless, the results of the present study are interesting since they question the common assumption that child-centeredness would be positive for learning and achievement. Conversely, the results

indicate that it is the good working habits (Boekaerts & Corno, 2005), such as extended writing, that make a difference.

4.4. Conclusions

The overall aim of the present study was to explore whether or not there were differences in reading ability between students from a computer supported and self-regulating learning environment and students from more traditional learning environments in grade two. In addition, the aim was to explore potential explanations for reading ability in the experimental group.

The analyses showed that the experimental group had a significantly better reading comprehension both on group level and for girls and boys separately, as well as a lack of gender differences in reading ability. Since reading ability in Sweden has decreased from 1991 to 2001 for 9-year olds (Martin et al., 2003), the fact that the data for the control group came from 1995 implies that the students from the control group could be assumed to read better than the experimental group whose data are from a later point of time; hence, these results are indeed positive. Moreover, the ratio of high achievers was much higher, and the ratio of low achievers was much lower in the experimental group as compared to the control group. These results indicate that this specific learning environment with extended computer use and self-regulation was positive for reading comprehension. Since it was not possible to separate the specific importance of learning environment and the computer use, this issue needs to be further investigated by using an experimental design and, for example, use established measurements of teacher-student interaction e.g., Questionnaire on Teacher Interaction (QTI) as used by Ferguson and Fraser (1998).

The SEM showed that the main explanatory factor for reading comprehension was the latent variable writing. The computer supported extended writing in the studied experimental context seems to promote reading comprehension in grade two. It is also noticeable that home literacy did not contribute to the explanation of reading comprehension at all. As pointed out, the present results must be considered somewhat tentative. Nevertheless, the current study can be considered to indicate how a non-traditional self-regulated computer supported learning environment with extended writing can influence and promote reading comprehension. Hopefully, this research will stimulate further exploration of the relationships of the intertwined variables used in this study.

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