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Closing the gaps – Improving literacy and mathematics by ict-enhanced collaboration

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ABSTRACT

Literacy and mathematics are necessary skills that for different reasons unfortunately not everybody acquires sufficiently. In OECD countries there is also a gender gap; boys lag behind girls in literacy but often outperform girls in mathematics (OECD., 2012). ICT (Information and communication technologies) may contribute useful tools to address both these problems but in order to effectively create better educational conditions there is yet a need to develop effective methods that combine ICT with key factors for learning. This research contributes to this by measuring effects of the "Write to Learn" (WTL) method. WTL lets children from 1st grade use several ICT tools to write texts and subsequently discuss and refine them together with classmates and teachers using digital real-time formative feedback and assessment. The central learning factor addressed, in mathematics as well as in literacy, is the written communication allowing the learners to interact with peers and teachers. WTL draws on methods from socio-cultural theory, including continuous social interaction and written real-time formative feedback among peers, using shared electronic forums for collaboration, thereby providing social meaning and increased learning of literacy and mathematics, among both boys and girls.

The study uses quantitative methods and two control groups, one using *traditional method* (no ICT) and one *using technology individually* (without integrated social interaction and formative feedback), to compare results from 502 students in grade 3 national tests in mathematics and literacy. WTL yields by far best results; higher average score both in literacy and mathematics, smaller gender gap, and significantly better results for the under-achievers. The ITU method performs worst, which shows that ICT use must be well integrated into the pedagogy to be useful.

1. Introduction

Improving literacy is a challenge across the world, for many reasons. The information society requires increased ability to handle information and interact collaboratively than the industrial society, and certainly than the agrarian one from which many people today take a step directly to the information society. Therefore, more people in the world need enhanced literacy skills to be able to find, select, interpret, analyze, and produce information relevant to them. This development also requires that educational systems equip young students with new skills and competencies, sometimes called 21st century skills

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(European Commission, 2007; European Commisson, 2010), which allow them to collaborate and contribute actively in ways more related to needs of social development than suited to an industrial mode of production (Ananiadou & Claro, 2009).

This leaves us with a serious challenge as to pedagogical methods for employing ICT in literacy development. While the amount of computers and other relevant technologies is increasing in schools there is considerable uncertainty among teachers concerning *how* to use new technology and digital tools for enhanced learning among students. There is generally a scarcity of tested such methods. Most research is very small-scale – one or a few classes – and there is no compelling evidence of direct positive influence of technology use (Means, Toyama, Murphy, Bakia, & Jones, 2009). While technology in itself does not lead to improvement of student results, it may well be used to reinforce pedagogic factors that have been shown to have positive impact.

Two such key success factors for learning in focus of this study are formative feedback and formative assessment.

According to Cohen (1985) feedback "… is one of the more instructionally powerful and least understood features in instructional design" (p 33). Feedback, when combined with effective instructions in classrooms is found to be very powerful in enhancing learning (Hattie & Timperley, 2007). It is in fact identified as one of the most important factors for learning (Hattie, 2009). Black and Wiliam (2009) argue that the quality of interactive feedback is crucial when determining the quality of a learning activity; feedback is hence a central feature of pedagogy. Mueller and Dweck (1998) discuss the importance of *how* feedback is delivered, showing that (teacher) praise for (student) effort strengthens the learning process while praise for intelligence may rather be counterproductive.

Another success factor is for students to give *formative feedback* to their peers. According to the literature review by Shute (2008), most research conducted in the area of formative feedback shows that good feedback can significantly improve learning processes. Formative feedback may benefit the learner through several cognitive mechanisms, both to identify a gap between a desired goal and the current level of performance and to bridge that gap, which motivates greater effort (Locke & Latham, 1990; Song & Keller, 2001). Formative feedback can also reduce students' cognitive load and is particularly important for those who are novices or struggle (Paas, Renkl, & Sweller, 2003).

Another key factor for learning is *formative assessment*. Unlike summative assessment, formative assessment involves "… the process of curriculum construction, teaching, and learning for the purpose of improving any of these three processes" (Bloom, Hastings, & Madaus, 1971 p 117). What is well suited to summative assessments does not necessarily serve its purpose for formative assessment on a daily basis in order to improve learning (Black & Wiliam, 2003). In particular, aspects of learning that are not easily quantitatively measurable may be crucial for formative assessment.

According to Black and Wiliam (2009), "Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted and used by teachers, learners or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited" (p 9).

In today's information society there is a need to develop effective methods for implementing key factors for learning making best possible use of ICT innovations. The method presented and assessed in the present study, Write to Learn (WTL), is based on a model for combining social and formative interaction between younger peers and teachers with innovative use of ICT for increasing the effects of those learning factors. Drawing on socio-cultural theory the method includes a social view of learning combining collaboration, formative feedback, and formative assessment with strategic ICT use.

There is also a gender gap in education. According to the OECD report, "Closing the Gender Gap Act Now" (OECD., 2012), boys in OECD countries lag behind girls in reading skills and are less likely to spend time reading for pleasure, but perform better in mathematics, even though that gap is narrower than the one in literacy. According to the national tests in Sweden in mathematics grade 3, there is a mixed picture and no systematic gender gap (Skolverket, 2014). In higher grades boys in Sweden perform slightly better than girls in the national mathematics tests, although girls still overall receive higher grades in both mathematics and literacy (Skolverket, 2014). Boys in high-income countries are also more likely to drop out of secondary education and young women are increasingly better educated than young men in many OECD countries. In order to reap the highest economic and social return on education investment it is important to find ways to reverse the imbalance and close the gender gap (OECD., 2012).

The WTL method was designed to make use of ICT in order to facilitate writing and improve feedback and formative assessment. This paper reports results from a test of the method on a total sample of 502 students from a Swedish city. The results of the intervention group are compared to two control groups, one using no ICT and one using ICT "spontaneously", i.e. without this specific method of structured, formative feedback and social interaction.

This research draws on an earlier pilot study ($n = 87$), in which we found that the test group outperformed the control group (Agélii Genlott & Grönlund, 2013). The present study goes on to test the effects of the same method on a larger sample of students ($n = 502$). We also include mathematics as observations during the pilot study suggested that the method would yield positive results also in that field of knowledge. From these indications, and from the knowledge of how written communication allows learners to engage and interact with peers in "… the cultivation of mathematical knowledge" (Brendefur & Frykholm, 2000 p 125) we hypothesized that the social context and formative feedback and assessment the method implements were conducive also for learning mathematics – in fact the most important factor as there were no math-specific ICT tools used. In this extended study, therefore, we include results in mathematics and compare WTL with not only traditional training but also with training using ICT without the WTL method.

2. Theoretical perspective

There is comprehensive research on reading and writing skills, and there are various theoretical perspectives. This research draws on socio-cultural theory developed from the work of Vygotsky (1962); Vygotsky and Eccles (1978) proposing that learning is an active process which also is not just an individual matter but develops within a social context. Hence, context is important for learning, (Hall, 2007). The role of the human mediator is defined by Vygotsky and Eccles (1978) through the notion that "… each psychological function appears twice in development, once in the form of actual interaction between people and the second time as an inner internalized form of this function" (Chaiklin, 2003). Socio-cultural theories emphasize the social, cultural, and historic situation of language (Street, 1984); (Barton, 2001). In this perspective, learning must be anchored in the learners' experiences, creativity, and interests (Frederickson & Cline, 2002; Liberg, 2006). Learning takes place in formal as well as in informal contexts, and important aspects of learning include use of tools and development of artifacts (Säljö, 2000; 2002). Luke and Peter (1997) add the dimension of critical thinking; reading is about engaging in, reshaping, and critically examining the ways in which the world is described. Reading and writing are culturally defined social activities and gaining literacy is about learning through communicating in social relations with parents, teachers, friends, and media. Texts always represent values and views. Literacy hence includes social use of language. In this perspective literacy activities in the classroom become crucial. Following a social-cultural perspective, the "Four literacy resources model" Luke and Peter (1997) specifies a set of practices that children need to participate in so as to develop into good readers;

- Breaking the code of written texts;
- Participating in understanding and composing meaningful written, visual and spoken texts;
- Using texts functionally;
- Critically analyzing and transforming texts.

Drawing on this theoretical perspective, and very practically using the four literacies model, the WTL method developed in this research includes teaching and learning activities designed for all four practices. WTL also extends the fourth practice, critically analyzing texts, by the use of formative feedback- and assessment. It also uses ICT tools for all stages, which distinguishes it from many other ICT-supported methods, even those using similar names.

3. Purpose and hypotheses

The purpose of the research is to test if the ICT-supported method WTL, Write To Learn – which implements some elements from socio-cultural learning theory, notably formative feedback and formative assessment – yields better student results than two other forms of literacy training; (1) "traditional", without ICT use and (2) using ICT but not the WTL method.

This study extends our previous pilot study (Agélii Genlott & Grönlund, 2013) both by size and by scope. It employs two control groups, a "traditional" (not using ICT at all) and one where ICT was used but in an individual manner without any specific method for learning through social interaction and formative feedback among classmates. In summary the study extends the previous one in the following ways:

1. A larger sample (n = 502);
2. Use of the standard national tests for Grade 3;
3. Separating the technology and the method factors by including also a third method where ICT is used but without the WTL method (hereafter called the "individual technology use" (ITU);
4. A longer time period. This study measured results after three school years as compared to one year in the previous study;
5. Including tests in mathematics.

The overall hypothesis of this study is that *ICT use in combination with a pedagogical method including formative feedback and assessment as a digital social interaction among peers improves results in literacy development and in mathematics*. This overall hypothesis is operationalized by the following more specific ones.

H1. WTL leads to higher student achievement in literacy compared to the traditional method.

H2. WTL leads to higher student achievement in literacy compared to the ITU method.

H3. WTL leads to higher student achievement in mathematics compared to the traditional method.

H4. WTL leads to higher student achievement in mathematics compared to the ITU method.

H5. WTL leads to better performance among low performers than the traditional method.

H6. WTL leads to better performance among low performers than the ITU method.

Since girls' overall better performance in school is often attributed to their better ability to adapt to the school environment and organize their work we also hypothesized that a more structured method and technical tools supporting a social

learning-oriented peer culture (Legewie & DiPrete, 2012) would improve the boys' results even more than the girls'. Hence the following additional hypotheses:

H7. WTL leads to a lower gender gap in performance than the traditional method.

H8. : WTL leads to a lower gender gap in performance than the ITU method.

The study provides empirical evidence that the WTL method is effective in both literacy and mathematics development and helps closing the gender gap.

More generally the study contributes by showing that ICT use in schools without structured integration with pedagogy is not effective but may in fact prove detrimental. It also shows that ICT can effectively be used for extended social learning activities and it provides evidence that social learning theory is a good base for teaching and learning.

4. The WTL method

The WTL (write to learn, first named iWTR for "integrated write to read") method was initially developed in 2011 with inspiration from Trageton (2003). The aim was to structure crucial aspects concerning how to integrate literacy education of young students with ICT so as to make the best use of the opportunities offered by technology. The overall aim was to increase literacy skills and close the gender gap among young students (Agélii Genlott & Grönlund, 2013). For the present study the method was further elaborated by improving certain key factors for learning. In particular, written social interaction within mathematics teaching was added, hence the name change to WTL. This extension was made due to indications of better student performance also in mathematics during the pilot study (ibid). WTL emphasizes collaborative learning and has been influenced by several effective pedagogical factors, in particular the ones mentioned above, feedback (Hattie, 2009; Hattie & Timperley, 2007), formative feedback, and formative assessment (Black & Wiliam, 2003; 2009; Shute, 2008). Other important pedagogical factors included in WTL model include visible learning (Hattie, 2009) and early learning of different literacy genres (Rothery, 1996).

4.1. The WTL cycle

WTL prescribes social use of ICT involving communication and written, formative feedback and assessment among students as well as between students and teachers. The method lets children from 1st grade use computers or tablets and a set of software tools to collaboratively write texts and subsequently discuss and refine them together with classmates and teachers. "Texts" in literacy training are various stories, in mathematics they are discussions about how to understand and solve mathematical problems. Children work in pairs writing texts, taking turns typing and reading. The child who is not writing provides both inspiration to formulating the text and a check that it is properly written. If needed the speech synthesis app ClaroRead is used to let the children check how their writing sounds. For interaction Google Apps for Education (GAFE) were used, mainly Google Drive and Google Sites. The students give each other written formative feedback through shared digital documents iteratively during the writing process (production of longer texts extends over several days or even weeks). Finally, they publish their written work on Google class sites where they get feedback on their final product from other readers. The contrast to other ICT-supported training is that formative feedback and assessment are used systematically and that ICT is used as an important medium for increasing the effects of the formative feedback. Hence WTL extends previous methods i.e. ASL (Trageton, 2003), by including ICT-based social work methods, using digital learning spaces and formative peer commenting for providing social meaning and formative feedback (Agélii Genlott & Grönlund, 2013).

The WTL method is based on a socio-cultural perspective integrating social interaction and collaborative learning as main features for learning. The method includes collaborative writing, formative feedback, formative assessment and publishing as main distinctive components. Supporting components include inspiration and pre-understanding ("Preview", Fig. 1), early learning of text genres, scaffolding, and different writing strategies. The general work process by which WTL lessons are carried out is designed as follows (illustrated in Fig. 1). In each phase of the WTL method the students use computers or tablets. All students have their own GAFE account and use different GAFE applications such as Google Sites (class web-sites) or Google Drive (shared documents) in accordance with the tasks defined by the teacher and with the different phases in the method. WTL is implemented in mathematics by letting the students create and solve mathematical problems through written collaboration, again communicating, solving problems, and publishing their solutions using the same GAFE applications. The WTL steps (Fig. 1) are:

1. With the aim of making learning goals visible and understandable also for the youngest students WTL takes its starting point in explaining, and in simple words writing down the goals and knowledge requirements of the Swedish national curriculum ("Lgr 11"; Skolverket, 2011). These goals are published on the same digital Google class site used for the student assignments, enabling the students to go back and read if needed.
2. "Inspiration/Preview" aims at arousing interest among the students, but also at providing them with the pre-understanding of the task that is necessary to create the very best conditions for each and every student to succeed. This can be done in different ways depending on the task as well as on different student needs. Technology used in this

Fig. 1. Steps in the WTL method (Agélii Genlott & Grönlund, 2013).

phase differs but previews are often videos used as a form of flipped classroom, meaning that tutorial or inspirational videos are published on the Google class site for the students to take part of and learn from before the lesson.

3. "Text type/writing strategies" refers to which text type/literacy genre the task concerns and consequently which kind of writing strategy to use. Technology used in this phase is mainly shared documents through Google Drive, where students learn from written examples given from the teacher.
4. "Collaborative Writing" represents social interaction and collaborative writing. The students are now starting to write either in pairs or individually but always sharing their texts with peers and teachers digitally thereby continuously both giving and receiving formative feedback during the writing process. The technology used here is mainly Google Drive.
5. "Formative Feedback & Formative Assessment/Publishing" refers to the continuous work of the students learning how to give and take formative assessment to each other from early years. As giving formative feedback is complex and requires certain skills, the students are continuously taught by means of instructions and practice in order to further develop skills of reviewing others' work in a formative way. Finally, the students publish the final version of their work on a web site, which gives them more readers and more final feedback. Technology used in this phase is Google Drive, and the final versions of the texts are published in Google Sites.
6. "Final assessment" is done by the teacher. Due to the consistent use of ICT throughout the process, all student texts and formative feedback produced and received by the students are available on the digital collaborative spaces, and are therefore all considered in the assessment. This step is often formative as well, aiming to help the students see what they have achieved so far in terms of the Lgr11goals and what the next steps are. Technology used in this phase includes all the student drafts and final work saved on the Google site. The teacher can also through the documents of Google Drive review the history of the drafts, this is important so as to understand the writing process of the students.

The above activities integrate technology use and physical oral communication throughout the process. An important part of WTL is that all students are given criteria (item 5 above) for writing formative feedback to their classmates with the aim of contributing to others' texts as well as increasing their own learning by cognitively reflecting and formulating written formative feedback. Publication is done to make sure texts are read by even more readers, primarily other students and teachers, but also by parents. This serves to increase the students' awareness of an audience and their knowledge concerning writing for recipients, and to make sure there are final responses to the published texts.

WTL is used in all subjects where linguistic abilities such as reading, writing, collaboration, and reasoning are important. It is already well known that linguistic abilities affect performance in mathematics, and that mathematics in itself is a specialized language. Brendefur and Frykholm (2000) categorize the various forms of mathematical communication as *uni-directional*, *contributive*, *reflective and instructional*. *Uni-directional communication* is often used in schools where teachers dominate the discussions by mostly lecturing knowledge passively received by the students. *Contributive communication* instead focuses on interactions between teachers and students but mostly by sharing and often without much deeper thought. *Reflective communication* is when students share their ideas, strategies, and solutions, thereby engaging in mathematical conversations. Central to *instructive communication* is modification of the students' mathematical understanding, where the written communication serves to expose the students' thinking. This helps the teachers to gain insights of the students mathematical thinking but also make them shape subsequent instruction. The use of WTL in mathematics education focuses mainly on four abilities specified in the Swedish mathematics curriculum; communication, reasoning, solving

problems, and learning different mathematical concepts. In WTL, students publish their written mathematical reasoning, thinking, and solutions in writing through shared documents or on the class site for their classmates to read, give feedback to, and/or to solve. In this way WTL serves to increase the linguistic foundation for reasoning and mathematical thinking, the logic being that improved mathematical thinking will lead to improved ability to deepen the mathematical understanding.

5. Method

The study included 502 students who had been exposed to different teaching methods over a period of three years during grades 1–3.

Student test scores in the National Standard Tests (NST) of literacy and mathematics were used to examine if the WTL method produced better results than other methods. Two control groups were used, one "traditional" without ICT and one using ICT but not the WTL method.

Potential bias caused by socio-economic factors was tested using the model for calculation of such bias that was used by the municipality in which the study was conducted; the test used the Pearson correlation index.

The Grade 3 NST is the only nationwide test carried out by all grade 3 students in Sweden. The NST tests a number of abilities related to reading, writing and mathematics with a total of 15 tests, 7 in mathematics and 8 in literacy. The NST also includes grading guidelines and rules for teachers, aiming at standardizing assessment and minimizing bias as far as possible. In addition, so as maximize conformance in assessment, the local school authority organizes collaborative assessment across schools. The NST is carried out in several steps during the same period (February-May 2013) in all schools. The NST is the most standardized test available and hence most appropriate to use for this study.

The three groups involved differ as follows.

1. The *WTL* is a structured way of integrating ICT from grade 1 when learning how to write and read. Teachers in the WTL group have attended a one-year community-wide course, theoretically and practically learning how to integrate ICT into the pedagogy of literacy and mathematics. Students learning how to read and write using the WTL, in addition to reading books as usual, continuously use class websites and other web arenas for collaboration publishing and formative feedback.
2. The *traditional method* (*no or sporadic technology use*) is learning how to read and write without ICT use. The first focus is on the reading, thereby identifying different letters, using the phonics method, sometimes combined with the whole word method. Handwriting often starts by learning one letter at a time to train the fine motor skills at the same time as working to break the code of learning how to read.
3. The *ITU* (*Individual technology use*) include teachers and students continuously using digital devices though without using (or having been trained in) the specific WTL method. The teachers in the ITU use ICT but not shared documents or web arenas for structured formative feedback between peers and teachers.

The study hence tested WTL in two ways: regarding the use of ICT tools and regarding the use of a specific social pedagogical method. The traditional method was used as control group for the ICT use, and the ITU method was used as control for the social interaction arrangements - such as the formative feedback supported by ICT - that were a crucial part of the intervention.

The distribution of classes into groups was done using both the documentation concerning which of the teachers who had attended the WTL course as well as information from school principals and course leaders with the knowledge of which method of the three included in this study that most appropriately described the pedagogy of the teachers. The latter test was done to (1) control that teachers who had attended the course actually used the method they had been taught, and (2) find any teacher who had not attended the course but used the method based on knowledge acquired from other sources. As the classification into different groups was not decided beforehand, this cannot have affected the teachers or the students in any way.

Test results from the Spring 2013 national tests were collected from the city's database (public schools only). The database contained all 696 students who started school in Fall 2011 and took the tests in Spring 2013. Due to incomplete data 194 students were excluded from the study. One major reason for missing test data is migration over the three years of primary school. One school was excluded because of inconclusive information concerning which teaching method was used. Other reasons are not known, but may include students being absent due to illness, travel, or other. In total, the sample includes data from all 502 students for which complete data was available. The total sample includes the results for students from 21 classes taught by 23 teachers in 11 public schools.

For privacy reasons student names and personal identity numbers were not extracted from the database. Data was analyzed by means of hypothesis tests using mean comparison and t-tests as well as Pearson's Chi-Square tests of independence. All analyses and tests in this study were done using the software STATA.

Of the 502 students, 247 used the WTL method, 128 the traditional method, and 127 the ITU method. Gender distribution was equal in the WTL and traditional groups (48% girls in both groups) while boys were in majority in the ITU group (61%) (Table 1).

Table 1
Total sample included in the study.

Method	Girls	Boys	% Girls	% Boys	Total
WTL	118	129	48%	52%	247
Traditional	61	67	48%	52%	128
ITU	50	77	39%	61%	127
Total	229	273	46%	54%	502

6. Results

This section presents the results for literacy, mathematics, and combined for the 15 test that together make up the national tests. Each test is graded by pass or fail, so all the numbers below refer to those students who have passed the tests.

6.1. Literacy

The results of this study show that students using the WTL method performed better than students in both other groups. In the WTL group 92 percent of the students passed all eight tests, which is better than the traditional group (79%) and the ITU group (77%). Concerning the gender perspective, while both boys and girls in the WTL group performed better than those in the other groups, the difference was greatest for the boys. WTL boys scored 18 percentage points better than the traditional group (7 for the girls) and 21 (5) compared to the ITU group. This means the gender gap is shrunk to 5 percentage units for the WTL method compared to 15 for the traditional method and 21 for ITU (Fig. 2). This supports hypotheses 7 and 8.

In the WTL group there was also less spread with no WTL student passing less than five of the eight tests. In both the other methods a lower share of students passed all tests and the spread was wider with lower minimum results (Table 2).

The statistical test, a two-sample *t*-test (Table 3), shows that the differences in means between WTL-Traditional and WTL-ITU methods are significant at the 0.05 level. The difference between the traditional method and ITU is not significant. Hypotheses H1 and H2 are hence supported; WTL students score significantly better than both other methods.

6.2. Mathematics

In the WTL group, 81 percent of the students passed all seven tests (Fig. 3). This is better than the traditional group (67%) and the ITU group (56%).

As regards the gender perspective, in the WTL group boys and girls performed equally well; 81 percent of both boys and girls passed all tests. This was considerably better than both control groups; the boys scored 52 percent and the girls 60 in the ITU group, for the traditional group the shares were 62 and 75 percent. This means the gender gap has shrunk from 15 percentage points for the traditional method and 10 for the ITU method to zero. The result supports hypotheses 7 and 8.

Table 4 shows that the mean was higher and the standard deviation was smaller in the WTL group than in both the others.

The statistical test, a two-sample *t*-test, shows that the differences in means between WTL-Traditional and WTL-ITU are significant at the 0.05 level (Table 5). Hypotheses H3 and H4 are hence supported.

6.3. Literacy and mathematics combined

Altogether, 78 percent of the WTL students passed all tests in both literacy and mathematic, to be compared to 59 percent for the traditional method and 50 for ITU (Fig. 4).

While both boys and girls in the WTL group performed better than those in the other groups, the difference was greatest for the boys. WTL boys scored 29 percentage points better than the traditional group (8 for the girls) and 31 (22) compared to the ITU group. The gender gap is shrunk to 3 percentage units for the WTL method compared to 24 for the traditional method and 12 for ITU (Fig. 4). This supports hypotheses 7 and 8. The numbers may make the ITU method seem better than the traditional one (as the gap is smaller) but it is not really; the smaller gap is not achieved by boys performing better but by girls performing worse overall using ITU due to the lower results in mathematics.

Also concerning the students who passed all 15 tests in both literacy (8) and mathematics (7) the WTL group scored better than both other methods. Table 6 shows that the mean was higher and the standard deviation lower in the WTL group compared to both the others. Further, no student in the WTL group passed in less than 9 out of the 15 tests while the lowest result in the traditional group was 7/15 and in the ITU 5/15. The better performance among low performers supports hypotheses H5 and H6.

The statistical test, a two-sample *t*-test, shows that the differences in means between WTL-Traditional and WTL-ITU are significant at the 0.05 level (Table 7).

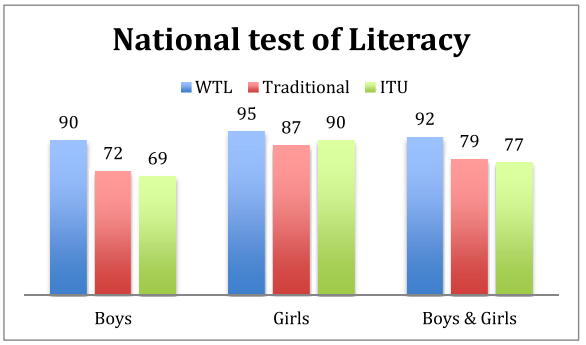

Fig. 2. Student results (%) in the national test of literacy, school year 3.

Table 2
Mean values of number of literacy NS-tests passed (max result = 8).

Method	Population	Mean	Std.dev	Min passed	Max passed
WTL	247	7.89	0.423154	5	8
Traditional	128	7.67	0.743575	4	8
ITU	127	7.57	0.996755	3	8

Table 3
Literacy. Two-sample *t*-test.

Methods	Differences (mean)	Std. Err.	t-value	Pr (T > t)
WTL-Traditional	0.13	0.035	3.81	0.000
WTL-ITU	0.15	0.036	4.23	0.000
Traditional - ITU	0.02	0.052	0.33	0.369

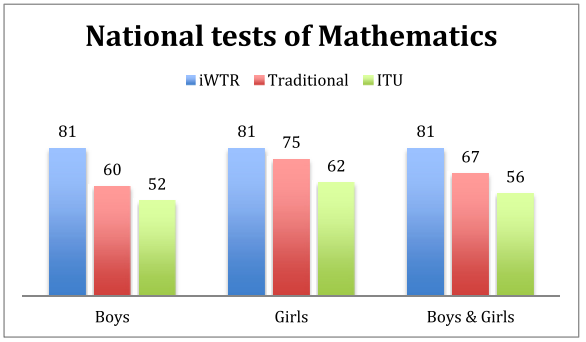

Fig. 3. Student results (%) in the national test of mathematics, school year 3.

Table 4
Mean values of number of mathematics NS-tests passed (max result = 7).

Method	Population	Mean	Std. dev	Min passed	Max passed
WTL	247	7.89	0.423154	5	8
Traditional	128	7.67	0.743575	4	8
ITU	127	7.57	0.996755	3	8

Table 5
Mathematics. Two-sample *t*-test.

Methods	Differences in means	Std. Err.	t-value	Pr (T > t)
WTL-Traditional	0.14	0.046	3.11	0.001
WTL-ITU	0.25	0.047	5.43	0.000
Traditional - ITU	0.11	0.061	1.86	0.032

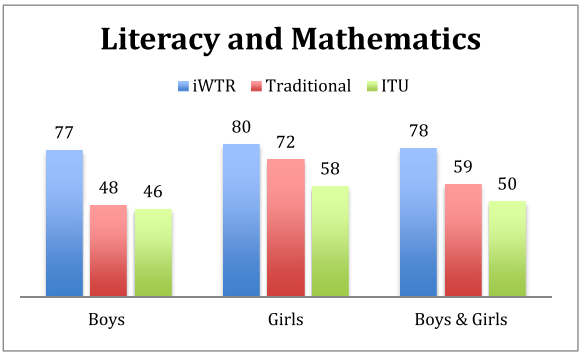

Fig. 4. Student results (%) in the national test of literacy and mathematics, school year 3.

Table 6
Mean values of literacy and mathematics in number of NS-tests passed (Max = 15).

Method	Number of students	Mean	Std.dev.	Min tests passed	Max tests passed
WTL	247	14.56	1.029597	9	15
Traditional	128	14.08	1.585413	7	15
ITU	127	13.65	2.010005	5	15

Table 7
Literacy and mathematics. Two-sample *t*-test.

	Differences in means	Std. Err.	t-value	Pr (T > t)
WTL	0.48	0.065	3.57	0.0002
Traditional	0.92	0.157	5.84	0.0000
ITU	0.43	0.227	1.91	0.0287

6.4. Test for gender gap

As shown above, boys overall improved more than girls by using the WTL method (Figs. 2–4). The differences are summarized in Tables 8 and 9. We tested the relation between gender and student results using Pearson's Chi2 test of independence. The result shows that gender does not significantly affect student results in literacy in the WTL group (Chi2 = 2.16, p-value = 0.141) whereas there are significant gender differences in both the traditional (Chi2 = 4.46, p-value = 0.035) and the ITU groups (Chi2 = 7.71, p-value = 0.005). This implies that the WTL method decreases the gender gap in literacy.

In mathematics the same pattern concerning gender dependence in WTL was found, that is, the dependence was much lower in the WTL group than in the others; in fact – as Table 9 shows – boys and girls performed equally well. However, even though the differences were considerably bigger in both the other groups they were not statistically significant in the Pearson test.

6.5. Test for bias

Potential bias in the results presented above might result from different preconditions at the schools. Therefore a few tests were made to control for such variables.

Potential bias caused by different teacher capability: All teachers taking part in the study had formal teacher education. On average the teachers had 11.5 years of teaching experience. The youngest two had 4 years of experience, the most experienced 39 years. This means all teachers fulfilled reasonable requirements of education and experience. There is no way to objectively

Table 8
Achievements & gender differences in literacy.

Method	Literacy		Difference
	Girls	Boys	
WTL	94.92	89.92	5.00
Traditional	86.89	71.64	15.25
ITU	90.00	68.83	21.17

Table 9
Achievements & gender differences in mathematics.

Method	Mathematics		Difference
	Girls	Boys	
WTL	81.36	81.40	−0.04
Traditional	75.41	59.70	15.71
ITU	62.00	51.95	10.05

determine individual teacher skills in literacy teaching as there are no quantified criteria for that and hence no standard test. Also, in all classes more than one teacher took part in teaching so there was good availability of teaching expertise.

The potential bias caused by socio-economic factors was tested using the model for calculation of such bias used by the city in which the test was done. The model, labeled the SWECO model after the company who developed it, is also used by some other cities. It is similar but more detailed than the one used by the Swedish national school authorities (national scores were not available as the national school authority does not make such calculations for primary schools). It measures the socio-economic status at school levels on the following factors; Parents education level, years since immigration, students' sex, parents' reception of government economic support, share of students living with both parents.

The SWECO index varied widely across the schools included in this test (Fig. 5). Pearson correlation index was −0.4006, which means there is no significant correlation between a school's SWECO index and its performance in the national tests. Fig. 5 illustrates the (lack of) correlation between SWECO index and school performance visually.

In view of these tests it is fair to say that neither teacher skill nor socio-economic factors influenced the results significantly.

7. Discussion

The purpose of this study was to see if student performance in literacy and mathematics was improved by the use of a specific method (WTL) which uses ICT support for a number of elements which earlier research has shown to be conducive for learning such as social interaction, formative feedback and formative assessment (Black and Wiliam (2009); Hattie, 2009).

The study compared student achievements in the Swedish national standard tests of literacy and mathematics in grade 3 for three teaching methods, the WTL, a traditional method (no ICT) and one with only individual ICT use (ITU). The overall hypothesis was that *ICT use in combination with a pedagogical method including formative feedback and assessment as a digital social interaction among peers improves results in literacy development and in mathematics*.

The study found that students using the WTL method achieved better results than both control groups, and most significantly compared to the ITU method. This is interesting since the ITU method includes students using the same digital devices as the WTL students, only without the WTL method with its formative feedback and assessment and the specific structure for integrating social interaction into the education designed based on the socio-cultural perspective. What mainly differentiates the WTL method from the ITU method therefore is the implementation of socio-cultural theory. In terms of technology use this includes the specific way of using the class website with the aim of integrating ICT as a way of creating

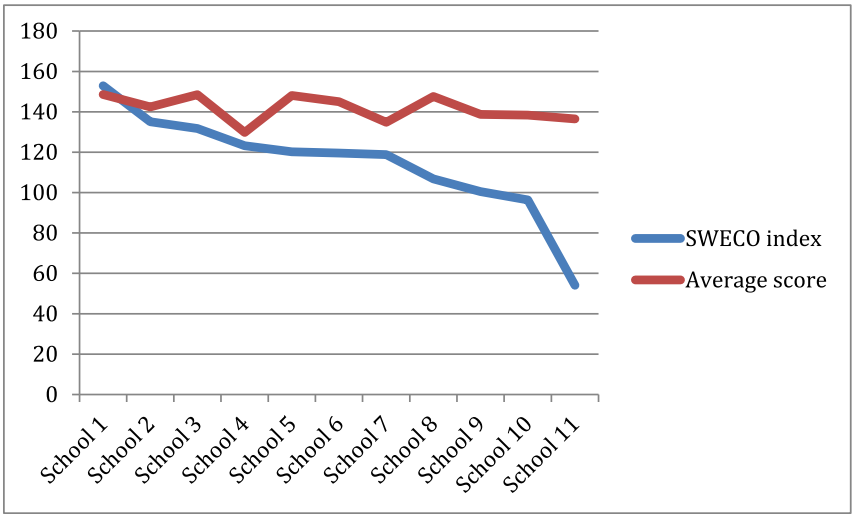

Fig. 5. SWECO index (blue line under) and schools' performance (red line over). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

effective arenas for social interaction, collaboration, formative feedback and formative assessment integrated into the pedagogy.

The WTL method also scored by far best in reducing the gender gap in performance. The gender gaps in both literacy and mathematics were much smaller in the WTL group than in the control groups. The most conspicuous result on this point was that in mathematics boys and girls performed equally well. In accordance with previous research on ICT use in various processes, this shows that a structured method integrating social interaction is beneficial for both boys and girls, and in both literacy and mathematics. The gain is the biggest and the most important for boys concerning literacy, in which subject they traditionally perform worse than girls. This supports the argument of Legewie and DiPrete (2012) that in particular boys benefit from school resources that "create a learning-oriented peer culture". This can in this case be attributed to the WTL method and the supporting use of collaborative ICT tools.

We find the good results in mathematics particularly interesting, as the WTL method does not include anything particular about numbers; it is mainly about communication. The findings imply that learning mathematics has a lot to do with understanding the problems to be solved and ways to solve them. This is learned through use of language. At least at this beginner level, learning mathematic is just as much, or more, about thinking and reasoning as about the numbers. WTL prompts teachers and students to discuss mathematical issues by formulating written mathematical problems, publishing them for others to solve, and thereafter reasoning together through formative feedback in written words. In comparison to the traditional method where the class communicates about these things orally, WTL provides *more* communication (more time spent on it as they both talk and write), *durable* communication (the texts stay for students to go back and recall), and *equal* communication (all participate, all have equal time for communication, no competition for attention). According to our test results these factors are crucial.

Today the WTL method is used more or less in all subjects that are based on reading and writing of some kind in the studied city. It is therefore possible that the WTL method is also affecting the achievements in other subjects in a positive way. Unfortunately we could not test that as the national tests in grade 3 only test literacy and mathematics.

One implication of the results is that method development is important in conjunction with ICT use. It is also important to organize dissemination of innovation so that effective methods do not stay undetected by the rest of the world in the classroom in which they were invented and first tested. This is a challenge in several ways. First, methods have to be developed and tested. Second, dissemination is difficult as, according to a 2013 Swedish study, 20% of the teachers are negative to ICT use and only 1/3 positive (SOU, 2014:13). This points to a leadership challenge, but also to the need to invest considerable time in dissemination of innovation. In our case study, the City had invested in more than one year of initial method development and pilot test and subsequently in three years of educating teachers. Even so, not all teachers have yet been educated and/or convinced of the benefits of making the effort to move to a new teaching method integrating ICT into the pedagogy. Although some teachers by themselves are early adopters of new digital technology, many others need much support in how to optimize the use of ICT in the pedagogy. It is therefore probably crucial that teachers are supported in this matter so as to avoid inequality amongst both students within schools as between schools (as pointed out by Samuelsson, 2014; Beckman, Bennett, & Lockyer, 2014).

The fact that the lowest performers – which include students with difficulties in reading and writing due to e.g. dyslexia, some kind of language disorder or problems with fine motor skills, or just slower development – scored so much better in the WTL group is important. While technology can compensate for e.g. lack of fine motor skills the study shows that such factors alone do not explain the results. As the factor differentiating the WTL and ITU methods is the social interaction using written language, we believe that the fact that students who suffer from such reduced abilities have been interacting on the same arena as their classmates in the WTL group, on the class website, thereby being able to take part in the social written interaction has increased their self-confidence and their interest in communicating by written language. This in turn might have had an impact on the WTL students' incentives to read and write even more.

The study also showed that the ITU method yielded the lowest student performance of all methods. This shows that ICT use in itself does not lead to better results but may indeed lead to worse. It is only when ICT is used to support other pedagogic factors that have been shown to have positive impact more efficient and effective, and does so in a systematic way, that the positive results occur. These results are in conformance with previous studies in the education field (Agélii Genlott & Grönlund, 2013; OECD, 2010), as well as in other fields (Brynjolfsson, 1993); ICT improves operations only in combination with effective process change.

8. Conclusion

This paper has reported a study of the effectiveness of an innovative pedagogical method including ICT in combination with social interaction, WTL (Write To Learn), as measured by student results on national standard tests in literacy and mathematics ($n = 502$). There were two control groups, one using traditional method (no ICT) and one using ICT individually (no ICT-supported social interaction).

The study finds that.

- WTL leads to higher student achievement in literacy as well and in mathematics than both other methods – the difference (combined) is 19 percentage points compared to the traditional method and 28 compared to the ITU method.

- WTL leads to better performance among low performers than both other methods– the results of the lowest performers are 80% better in WTL than in the worst performing method.
- WTL leads to a lower gender gap in performance than both other methods – in mathematics boys improved their performance up to the level of girls, in literacy the girls did only 3% better. Overall boys performed almost 30 percentage points better using WTL compared to both other methods.

The contribution to research is to quantitatively compare a model that integrates ICT and theory-based pedagogy into the education of literacy and mathematics with two other commonly used methods concerning its effectiveness in producing better student results in the national standard tests in literacy and mathematics in school year 3. The study showed that use of ICT based on a socio-cultural perspective and including effective arenas for collaborative learning, feedback and formative assessments are key factors for learning.

The contribution to practice is empirical evidence that the method is effective in both literacy and mathematics, and that ICT use without integration in social learning activities is not effective but may in fact prove detrimental.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2016.04.004.

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