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ABSTRACT

This study examined the collateral effects of WiggleWorks, an interactive literacy program, in two settings: a cohort study comparing random samples of grade 1-2 students (n=452) before and after software implementation and a longitudinal sample tracing students from Kindergarten to grade 1 (n=126). WiggleWorks contributed to greater student use of computers, and enhanced computer skills, computer self-efficacy and (in grade 1 only) enjoyment of computers. Positive effects were observed regardless of whether the school received new hardware at the time of software delivery or used existing equipment of sufficient power acquired a year earlier. In addition, following WiggleWorks implementation, teachers became more confident about their ability to use computers and were more likely to assign students to self-directed exploration of computer functions. The study suggests that the high cost of adopting interactive literacy software may be warranted if the program has benefits beyond its contributions to reading and writing skills. Four tables present statistics. Contains 37 references. (Author/AEF)

Collateral Benefits of an Interactive Literacy Program For Grade 1/2 Students and Their Teachers[1]

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This study examined the collateral effects of WiggleWorks, an interactive literacy program, in two settings: a cohort study comparing random samples of grade 1-2 students (N=452) before and after software implementation and a longitudinal sample tracing students from Kindergarten to grade 1 (N=126). Wiggleworks contributed to greater student use of computers, enhanced computer skills, computer self-efficacy, and (in grade 1 only) enjoyment of computers. The univariate effects were of small to medium size and were robust across grades and genders. Positive effects were observed regardless of whether the school received new hardware at the time of software delivery or used existing equipment of sufficient power acquired a year earlier. In addition, following WiggleWorks implementation, teachers became more confident about their ability to use computers and were more likely to assign students to self-directed exploration of computer functions. The study suggests that the high cost of adopting interactive literacy software may be warranted if the program has benefits beyond its contributions to reading and writing skills.

Previous research on computer-based literacy programs has produced mixed results: weak impacts on standardized reading and writing tests with more positive effects on literacy processes. In this article we present evidence showing that computer-based literacy programs have important collateral benefits that may be as important as their intended learning outcomes.

Motivation for the Study

Evaluations of literacy programs have focused on their impact on students' reading and writing competence, with discouraging results. Three meta-analyses (Bangert-Drowns, Kulik, & Kulik, 1985; Becker, 1987; Christmann, Badgett, & Lucking, 1997) located 12 non-overlapping studies of the effects of computer-based instruction on standardized literacy measures: 9 of the studies produced effect sizes below .20 (ranging from -.31 to .15). Only four effect sizes (from three studies) were above .40.

A more optimistic picture has emerged from studies examining the contribution of computers to students' writing processes. For example, Jones and Pellegrini (1996) found that

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grade one students produced better narratives with more lexical items and higher cohesion in their texts when they wrote on the computer. Verhoef and Tomic (1996), in a narrative review, found that when students use computers to write there is improved text quality, easier revision and more insight into the writing process. They argued that students have more positive attitudes to writing with a computer because it is easy to insert graphics, revise text, and produce a professional looking product. Verhoef and Tomic suggest that less able writers benefit from software supports such as a database to write from and word processing programs' grammar and spelling functions.

A new generation of interactive literacy programs have been developed to take advantage of the powerful processors available in Pentium-generation PCs. Our study examined one of the most popular programs for young children, WiggleWorks.

No studies of the effects of Wiggle Works have been published but the program distributors (Scholastic) have released two reports. Coles, Brailsford, and Hayden (n.d.) provided rich qualitative data on the implementation of WiggleWorks. Schultz (n.d.) found that grade 1 students using Wiggle Works over a six-month period outperformed a matched control group on all reading and writing measures. Both studies were of short duration and there was only one computer per classroom. In addition both investigations examined only student literacy effects of the program without attending to other student and teacher outcomes. The narrow focus on reading and writing skills might conceal student benefits such as the acquisition of particular computer skills and attitudes that enable subsequent learning with computers and teacher benefits such as increased confidence in their ability to teach with computers.

Our rationale for anticipating collateral student benefits from interactive literacy programs like WiggleWorks is based on Bandura's (1997) social cognition theory. At the core of Bandura's theory is self-efficacy: an individual's expectation that he or she will be able to perform specific actions that contribute to desired ends. Changes in ability perceptions lead to changes in student effort and motivation (MacIver, Stipek, & Daniels, 1991). Self-efficacy contributes to achievement directly and indirectly through goal setting and effort enhancement (Pajares, 1996). Social cognition theory predicts that if students have enactive mastery experiences (i.e., they successfully use the computer to achieve valued ends such as reading an interesting story or creating their own story), expectations about their capacity to perform subsequent computer tasks will increase. Positive self-efficacy beliefs about their ability to use computers will lead students to set higher goals for computer-based activities and persist through obstacles. Anticipations of success will increase student willingness to engage in computer tasks and students are more likely to be successful because of the additional effort expended. The result will be higher computer skills. Higher skill will create new mastery experiences, stimulating higher levels of confidence. As the cycle continues, student attitudes to working with and learning from computers will become more positive. By the same token if students' computer experiences are negative, failure will have a depressing effect on efficacy beliefs, thereby reducing computer self-efficacy (confidence), and willingness to seek opportunities for new computer experiences.

WiggleWorks is likely to have these effects because it provides students with scaffolding to accomplish meaningful tasks. Its effects are likely to be magnified since it is used virtually every day as an integral component of the language program. From social cognition theory we predict that WiggleWorks will (i) increase student use of computers, (ii) heighten student confidence in their ability to complete computer tasks successfully, (iii) develop students' computer skills, and (iv) contribute to more positive attitudes to computers.

The collateral student benefits of WiggleWorks may be moderated by gender. Although gender differences tend to be small (e.g., Bannert & Arbinger, 1996 found that gender explained 5% of the variance in computer outcomes), they are consistent. Males are more likely than females to use computers (e.g., Robertson et al., 1996), to be more confident about their computer abilities (Murphy, Coover, & Owen, 1988; Ogletree & Williams, 1990; Siann, Macleod, Glissov, & Durndell, 1990), to be more resistant to failure experiences (Nelson & Cooper, 1997), and to have more positive attitudes to computing (Badagliacco, 1990; Miura, 1987). Student outcomes might also be influenced by parental attitudes, although previous research has given little attention to the role of parents in computer-based learning. Several researchers (e.g., Siann et al., 1990) have attributed gender differences in computer outcomes to early socialization of children by parents. Males are more likely than females to report support from parents for computer-based learning (Reinen & Plomp, 1997). We anticipated that the student effects of WiggleWorks would be affected by parental attitudes to the use of computers in school and by parents' use of computers.

Our rationale for anticipating collateral teacher benefits was also based on social cognition theory. We predicted that implementation of WiggleWorks would influence teachers' (i) personal use of computers (because the program contains management functions such as a facility for tracking student performance) and (ii) their use of computers in delivering the language program. If these experiences were positive, (iii) teacher confidence in their ability to accomplish personal goals and (iv) teach with computers will increase. Teacher confidence will in turn enhance teachers' willingness to use computers and contribute to (v) more positive attitudes to the instructional use of computers.

We anticipated that the collateral teacher benefits of computers would be moderated by teacher characteristics. Teachers with greater computer experience are more willing to use computers in the classroom (Greenberg, Raphael, Keller, & Tobias, 1998; Nash & Moroz, 1997; Woodrow, 1991) and have greater confidence in their ability to use them effectively: Nash and Moroz (1997) found that teachers' personal use explained 32% of the variance in computer confidence. We used computer ownership as a proxy for prior experience (see Levine & Donitsa-Schmidt, 1998 for a review of the evidence linking ownership to experience). Previous research has found that gender differences are smaller among teachers than students. We did not investigate teacher gender differences because there were few male teachers in our K-grade 2 sample.

Previous research has often confounded hardware and software effects since software is frequently introduced with a hardware upgrade. We conducted our study of the collateral benefits of WiggleWorks in two sites that received an infusion of information technology resources. In the first site, Hastings, we used a cohort design to assess the overall impact. In this analysis we could not distinguish hardware from software effects. In the second site, Peterborough, we used a longitudinal design to disentangle the effects of the software from the impact of increased hardware. We were guided by two general research questions:

1. What are the effects of interactive literacy software on students' computer skills, self-efficacy beliefs, and attitudes?

2. Are the effects of software on students independent of hardware effects?

3. Are the student effects of WiggleWorks moderated by gender and parent influence?

4. What are the effects of interactive literacy software on teachers' computer skills, expectancies, and attitudes?

Method

Sample

In Hastings, the May 1997 sample consisted of five randomly chosen students from each grade 1 and 2 classroom (N=221) and their teachers (N=53) in a random sample (50%) of schools. In fall 1997 these schools received hardware (three Pentium computers for each grade 1 and 2 classroom) and WiggleWorks software. The April 1998 sample consisted of five students from the same classes (N=231)[2] and their teachers (N=50). Slightly more than half the students (52%) were female, with mean age of 6.6 years in grade 1 and 7.5 years in grade 2. The teachers were overwhelmingly female (93%) and very experienced (more than half had taught for more than 20 years).

In Peterborough, the 1997 sample consisted of five randomly selected students in each Kindergarten class[3] (N=147) and their teachers (N=36). The mean student age was 5.6 years and 52% were female. In fall 1997 half the Peterborough schools received hardware (four Pentium computers for each grade 1 classroom) and WiggleWorks software. The remaining schools received no hardware (because they had acquired similar hardware in the previous year) but did receive WiggleWorks software. The 1998 sample consisted of the same students (N=126) and their grade 1 teachers (N=37). All the teachers in the Peterborough sample were female and almost half had taught for 20 years. We also obtained data from 149 parents in the fall of 1997.

Instruments

There were three sets of student computer outcomes. The first consisted of performance tasks measuring *student computer skills*. Teachers administered the tasks individually and recorded the amount of support each student needed to be successful:

1= no prompts (e.g., "push the Enter key")
2=general encouragement (e.g., "this is something you have done before")
3=a specific clue (e.g., "look for a large key to push")
4=exact directions (e.g., "push this key [pointing] marked Enter")

[2] We drew a new random sample of grade 1 students (N=124) and re-tested students in grade 2 in 1998, who had been in grade 1 in 1997 (N=107).
[3] An invitation was extended to all schools prior to implementation: 64% schools volunteered.

The computer skills were selected from the skills set in WiggleWorks and were arranged in blocks of increasing difficulty: 5 *keyboard skills* (e.g., can demonstrate the use of the letter keys), 5 *basic student computer literacy* items (e.g., can open a file), 5 *word processing* items (e.g., can delete spaces, words, sentences), 4 *software applications* (e.g., can load a program), and 5 *graphics* items (e.g., can draw a picture using graphics). Items were averaged to produce 1-4 scores for each of the five skill sets. Scores were inverted so that a high score was positive.

For the second student outcome, *student self-reported computer use,* students indicated how often they engaged in each of 8 computer activities, using a 3-point scale for weekly (happy face), less than weekly (neutral face), and never (sad face). The 8 items were averaged to produce a 1-3 score.

The third set of outcomes consisted of two student cognition measures. For *student enjoyment of computers* students used a 3-point scale containing words (I really like it, it's OK, and I do not like it) and graphics (happy, neutral, and sad faces) to indicate their enjoyment of 8 computer activities. Items were averaged to produce a 1-3 score. For *student computer self-efficacy* students used the same words and graphics scale to indicate how confident they were in their ability to perform 10 computer tasks. Items were averaged to produce a 1-3 score. Students also indicated their *age* (4-9) and *gender* (boy/girl).

There were three sets of teacher outcome measures. The first set consisted of three measures of teacher practice. *Teacher's personal computer use* consisted of eleven items in which teachers indicated on a 7-point scale (0, 1-2, 3-5, 6-10,11-15,16-20, 20+) how many times per month they used a computer for various purposes (e.g., word processing, database management). The items were averaged to create a 1-7 score. *Self-directed student exploration* consisted of 8 items for which teachers indicated the number of minutes per week the typical student would be engaged in self-directed exploration of each computer use (e.g., listening to a story). For *direct teaching of computer skills* teachers indicated how many minutes per week they would spend on direct instruction of same 8 categories of computer use. Teachers responses to a 4-point scale (0,1-15, 16-30, 30+) were averaged to produce a 1-4 score on each measure.

The second set consisted of four measures of teacher self-efficacy. Teachers used a 5-point scale, anchored by "very sure" and "very unsure", to indicate how confident they were about 17 personal computing tasks (adapted from Murphy, Coover, & Owen,1988) and 8 teaching tasks (e.g., teaching students how to use a computer to write a story). An exploratory factor analysis of the 25 items produced four factors explaining 66% of the variance (Ross, Hogaboam-Gray, & Hannay, 1998). The pattern matrix loadings were used to select items for four self-efficacy scales: *teacher confidence in basic computer skills, teacher confidence in advanced computer skills, confidence in teaching language uses of the computer*, and *confidence in teaching other uses of the computer.* Items within each scale were averaged for a 1-5 score.

Teacher attitudes to the instructional use of computers, the third set of teacher outcomes, consisted of 9 items adapted from Davidson and Ritchie (1994). Six items measured *personal values and beliefs* (e.g., "I value teaching with technology") and three items measured *professional views* (e.g., "I think quality instruction using technology will enhance my teaching"). Teachers responded using a 5-point Likert scale. Items within each scale were averaged for a 1-5 score. Teachers also provided demographic information: *teacher gender* (male or female), *years teaching* (1-5, 6-10, 11-15, 16-20, 21+), *grade taught* (SK, 1, 1/2, 2, 2/3, 3, 3/4), and *teacher home computer ownership* (yes/no).

Parents, in Peterborough only, completed a survey in October 1997. *Parent attitudes to instructional use of computers* consisted of 15 Likert items (e.g., "I think students are more eager to learn when they use computers") measuring parent perceptions of the value of using computers to learn (adapted from Carlton & Birkett, 1995; Davidson & Ritchie, 1994). *Parent computer use* was a single item measuring how often the parent used a computer (daily, weekly, monthly, not at all); scores on the item were used to distinguish users from non-users.

Treatment

WiggleWorks consists of 72 trade books, audio tapes, and a large array of computer-based activities. There are multiple options that can be adjusted by the teacher for each child. For example, in Read Aloud pupils can listen to a story, read along with or without support, and record and play back their reading. Words, lines or sentences can be highlighted on the screen and pronounced by the computer. Pupils can build word families and spelling lists. Writing options include composing structured cloze texts, writing in response to a picture, and free writing. The Portfolio Management function provides for a reading record of each child and storage of writing and reading samples. Assessment guides include checklists of skills, running records, benchmark books and interview forms. A lesson plan with a variety of suggested learning activities is provided for each book. WiggleWorks combines skills based training with a holistic approach to language teaching.

In each site teachers participated in three half-day in-service sessions, delivered over two months, that provided direct instruction of the basic and optional features of the software. Teachers were also given self-directed opportunities to explore what WiggleWorks could do. Presenters, all experienced teachers who pilot tested WiggleWorks in the previous year, provided examples of how the program could be integrated with teachers' existing language programs.

Analysis

To examine the student effects of WiggleWorks we conducted a series of multivariate analyses of variance on the Hastings cohort data using the general linear model program in SPSS (a regression approach to analysis of variance). For each set of student outcomes (computer skills, use, and cognitions) we examined multivariate and univariate effects. In these analyses there were three between-subject variables: year (1997 or 1998, i.e., before and after WiggleWorks), gender (male or female), and grade (1 or 2). We focused on the main effects of year and two-way interactions of year with other variables. To separate software from hardware effects we repeated the analyses for the Peterborough longitudinal sample which tracked students from Kindergarten (1997) to grade 1 (1998). The Peterborough analyses examined multivariate and univariate effects for the same dependent variables. There were three between-subjects variables: gender (male or female), grade (1 or 2), and parental use of computers; there was one within-subjects variable time (1997 or 1998, i.e., before and after WiggleWorks).

To examine the teacher effects of WiggleWorks we conducted a series of multivariate analyses of variance in which the dependent variables were teachers' use of computers, teacher efficacy beliefs, and attitudes to computers. There were three between-subjects variables: year (1997 or 1998), teaching experience (1-20 years or more than 20 years), computer ownership (yes or no), and district (Hastings or Peterborough).

Results

Table 1 displays the reliabilities, means and standards for the student outcome variables in the study. Most alphas were in the .70s and .80s, with two in the .60s. Parental attitudes to computers (alpha=.84) and other independent variables are not shown.

Table 1 About Here

To determine the effects of WiggleWorks on Hastings students, we conducted a series of multivariate analyses of variance using GLM. In the first round, the dependent variables were five sets of student computer skills. The between-subject variables were year (before and after the introduction of WiggleWorks), grade, and gender. The interactions of year with grade and year with gender were also examined; all other interactions were suppressed. The top panel of Table 2 shows there were significant multivariate effects. Student computer skills were higher after the introduction of WiggleWorks in 1998 than they were prior to WiggleWorks in 1997. The program accounted for 25% of the variance in computer skill scores, a large effect. In addition, grade 2 students scored higher than grade 1 students, accounting for an additional 10% of the variance. None of the other multivariate effects (gender and the two-way interactions with year) were statistically significant. The bottom panel of Table 3 shows the significant univariate effects of year and two-way interactions with year. The table shows that WiggleWorks made a statistically significant contribution to each of the five sets of computer skills. The strongest impact was on software applications and graphics, two key components of WiggleWorks; the weakest were for keyboarding and word processing with basic computer literacy in the middle. These are small to medium effects. There was also a year by grade interaction: WiggleWorks had a greater impact on the word processing skills of grade 1 than grade 2 students but the effect, as shown in the table, was small. In addition, not shown in the table, there were small main effects for grade (eta squareds ranged from .02 to .08) for each of the five skills: In each case, grade 2s outperformed grade 1s. There was also a small main effect of gender [$\underline{F}(1,419)=4.480$, $\underline{p}=.035$, eta squared=.01] effect for word processing skills only: females scored higher than males.

Table 2 About Here

The second set of Hastings student outcomes concerned student cognitions about computers. The dependent variables were enjoyment of computers and computer self-efficacy (confidence in completing computer-based tasks). The between-subject variables were year (before and after the introduction of WiggleWorks), grade, and gender and two-way interactions with year. The top panel of Table 2 shows there were significant multivariate effects. Student cognitions about computers became more positive after the introduction of computers (11% of the variance). There were also small grade and year by grade interactions accounting for small additional portions of the variance. Examination of the univariate results in the bottom panel of

Table 4 indicated that WiggleWorks contributed to higher computer self-efficacy but had no main effect on student enjoyment of computers. The bottom panel also shows that a significant year by grade interaction: WiggleWorks contributed to higher enjoyment of computers in grade 1 but not in grade 2. There was also one additional main effect: Student confidence in using computers was higher in grade 2 than in grade 1 [$F(1,445)=22.19$, $p=.000$, eta squared=.05].

Finally, the effect of WiggleWorks on Hastings students' use of computers was investigated in a univariate analysis in which the dependent variable was the frequency students reported engaging in a variety of computer activities. The between-subject variables were year, grade, and gender. Student use increased after the introduction of WiggleWorks [$F(1,446)=92.05$, $p=.000$]; participation in the program explained 17% of the variance in computer use, a medium size effect. Males were slightly more likely than females to report higher computer use [$F(1,446)=6.00$, $p=.015$, eta squared=.01]. There were no other significant effects.

These results indicate that the introduction of WiggleWorks had positive effects on students' computer skills, self-reported use of computers, and confidence in their ability to complete computer-based tasks. There was also an increase of enjoyment of computers in grade 1 only. But WiggleWorks was implemented in Hastings simultaneously with the introduction of more powerful hardware. It is possible that the positive effects might be the result of being able to use other kinds of software that were previously unavailable because they could not run on less powerful machines. It is also possible that the positive student effects were the result of increased practice because more machines were available.

The Peterborough sample enabled us to disentangle software from hardware effects. In Peterborough half the schools received WiggleWorks software the year after they had received new hardware (old equipment schools) while the remaining schools received software and hardware simultaneously (the new equipment schools). In the first multivariate analysis of variance the dependent variables were the five sets of computer skills and the within-subject factor was time (skills were assessed in 1997 prior to WiggleWorks implementation and in 1998 after implementation). Between-subject factors were gender, age, equipment, and a variable not included in the Hastings sample, parental use of computers[4]. Grade was confounded with time: students were tracked from kindergarten to grade 1. In the analysis we examined main effects and two-way interactions with time.

The top panel of Table 3 displays the multivariate results. There was a large effect for time: Peterborough students' computer skills increased substantially during the project. There were significant time by equipment and time by parent computer use interactions. None of the other multivariate main effects and interactions were significant. The bottom panel of Table 3 shows the univariate effects. There were substantial increases in all five computer skill areas after WiggleWorks was introduced. The effect sizes were substantially higher in Peterborough than in Hastings because the Peterborough results confounded the effects of WiggleWorks with maturation. Of greatest interest is the equipment by time interactions, which reached statistical significance only for student use of graphics. Students in old equipment schools increased their

[4] We had intended to include parental attitudes to instructional uses of computers as an independent variable in the student analyses but we dropped it as a potential predictor because parental attitudes did not correlate with any of the dependent variables.

graphics skills to a greater extent than students in new equipment schools. This result suggests that the provision of interactive literacy software had a positive impact on student computer skills independent of access to more powerful computers. The other significant interaction in Table 3 indicates that WiggleWorks had a greater impact on the keyboarding skills of children whose parents were not computer users than on students of computer using parents.

Table 3 About Here

Not shown in Table 3, but reported here for the sake of completeness, are other univariate main effects. Girls outperformed boys on basic computer literacy [$F(1,120)=5.51$, $p=.021$, $eta^2=.05$] and word processing [$F(1,120)=4.15$, $p=.044$, $eta^2=.04$]. Six-year olds scored higher on keyboarding than 5-year olds [$F(1,120)=7.31$, $p=.008$, $eta^2=.07$]. Students in new equipment schools outperformed students in old equipment schools in keyboarding [$F(1,120)=4.53$, $p=.036$, $eta^2=.04$] and basic computer literacy [$F(1,120)=6.44$, $p=.013$, $eta^2=.06$]. Finally, children of parents who used computers had stronger keyboarding skills than the children of nonusers [$F(1,120)=9.11$, $p=.003$, $eta^2=.08$].

The top panel of Table 3 also shows the multivariate results when Peterborough student cognitions about computers were examined. There was a significant multivariate effect for time explaining 40% of the variance in student cognitions [$F(2,120)=40.66$, $p=.000$]. There were also multivariate main effects for age and equipment. The univariate results indicated that the multivariate effect of time was due to an increase in computer self-efficacy [$F(1,121)=81.71$, $p=.000$] following WiggleWorks. Enjoyment of computers was not affected. There were no univariate interactions with time. Not shown in Table 3 are significant between-subject effects, reported here for the sake of completeness: Before and after WiggleWorks implementation, females enjoyed computers more than males [$F(1,121)=4.75$, $p=.031$], six year olds enjoyed computers more than five-year olds [$F(1,121)=4.63$, $p=.033$], students in old equipment schools had more confidence in their computer abilities than students in new equipment schools [$F(1,121)=4.44$, $p=.037$], and six year olds were more confident than five-year olds [$F(1,121)=18.43$, $p=.000$].

Examination of WiggleWorks effects on Peterborough students' self-reported use of computers, using the same analysis design, revealed a within-subjects effect for time [$F(1,129)=61.18$, $p=.000$] explaining 32% of the variance. Students reported using computers more after the introduction of computers. There were no interactions of time with equipment or with the other between-subject factors.

The longitudinal analysis of the Peterborough student data confirmed the findings from the Hastings cohort comparison. WiggleWorks contributed to stronger computer skills, greater computer use, and increased computer confidence. Although confounded by maturation (unlike the Hastings results), the Peterborough effects were robust. There was a consistent program effect regardless of whether schools received new hardware at the same time as the interactive literacy software or used the hardware they obtained a year earlier. There was only one significant interaction with equipment: WiggleWorks made a greater impact on student graphics skills in schools with old than with new hardware.

Table 4 displays the reliabilities, means and standard deviations for the 1997 and 1998 teacher data. The reliabilities were adequate (.76-.94). We conducted a series of multivariate analyses of variance in which the dependent variables were teachers' use of computers, teacher efficacy beliefs, and attitudes to computers. There were three between-subjects variables: year (1997 or 1998), teaching experience (1-20 years or more than 20 years), computer ownership (yes or no), and district (Hastings or Peterborough). We did not examine the effects of equipment because there were too few teachers in the old equipment schools.

Table 4 About Here

We began by examining teachers' use of computers. There were significant multivariate effects only for experience [$F(3,128)=2.75$, $p=.045$, $eta^2=.06$] and district [$F(3,128)=4.34$, $p=.046$, $eta^2=.09$]. There was one univariate effect for year. The amount of classroom time devoted to self-directed student exploration of software increased from 1997 to 1998 [$F(1,130)=4.63$, $p=.033$, $eta^2=.03$]. There were no other year effects or interactions. The amount of time teachers spent in direct instruction in computer skills was higher for experienced than inexperienced teachers [$F(1,130)=5.88$, $p=.017$, $eta^2=.04$] and for Hastings than Peterborough teachers [$F(1,130)=8.61$, $p=.004$, $eta^2=.06$].

There was a multivariate effect for year [$F(4,128)=5.35$, $p=.001$, $eta^2=.14$], teacher perceptions about their computer abilities were more positive after WiggleWorks than they were before. There was also a multivariate year X teacher experience interaction. There were multivariate main effects for experience [$F(4,128)=2.90$, $p=.025$, $eta^2=.08$] and for computer ownership [$F(4,128)=3.89$, $p=.005$, $eta^2=.11$]. None of the univariate effects for year were statistically significant but there were several two-way interactions with year. Teachers with less teaching experience benefited more from WiggleWorks than more mature teachers. Less experienced teachers became more confident about their ability to handle tasks requiring basic [$F(1,131)=6.62$, $p=.011$, $eta^2=.05$] and advanced [$F(1,131)=5.79$, $p=.018$, $eta^2=.04$] computer skills and about their ability to use the computer in language class[5] [$F(1,131)=7.86$, $p=.006$, $eta^2=.06$]. Teachers who owned computers continued to be relatively confident about their ability to use computers to teach skills other than those required by language but teachers who did not have a computer at home became less confident about their ability to teach these skills [$F(1,131)=4.05$, $p=.046$, $eta^2=.03$].

There were also univariate main effects, included for the sake of completeness. Less experienced teachers were more confident than mature teachers about their ability to handle tasks requiring basic [$F(1,131)=9.45$, $p=.003$, $eta^2=.07$] and advanced [$F(1,131)=4.62$, $p=.033$, $eta^2=.03$] computer skills and about their ability to use the computer in language class [$F(1,131)=4.78$, $p=.031$, $eta^2=.04$]. Computer owners were more confident than nonowners about their ability to handle basic computer tasks [$F(1,131)=7.05$, $p=.009$, $eta^2=.05$] and to use the computer to teach in domains other than language [$F(1,131)=9.31$, $p=.003$, $eta^2=.07$].

[5] Computer-based language tasks consisted of using a computer to write a story, read a story, draw a picture, listen to a story and listen to sounds. Nonlanguage tasks were math, using a CD-ROM and games. All the language tasks were included in WiggleWorks; none of the nonlanguage tasks were.

WiggleWorks had no effect on teacher attitudes to computers. The only multivariate effect was for district [$F(2,137)=4.32$, $p=.015$, $eta^2=.06$]. The only univariate effects were for district as well. Teachers in Hastings had more positive personal [$F(1,38)=7.99$, $p=.005$, $eta^2=.06$] and professional [$F(1,138)=5.53$, $p=.020$, $eta^2=.04$] attitudes toward computers than Peterborough teachers. There were no effects for year or interactions with year.

In summary, WiggleWorks had a much smaller impact on teacher than student outcomes. The few significant effects were all positive: After WiggleWorks teachers were spent more time assigning students to self-directed exploration of programs and they had higher expectations about their abilities to use a computer.

Discussion

The first research question asked about the collateral benefits of WiggleWorks for students. In the Hastings sample we found that after the software was introduced, there were increases in students' use of computers, computer skills, confidence in using computers, and enjoyment of computers, as predicted by social cognition theory. These results were robust. Student benefits were observed across grades and genders. A significant main effect of WiggleWorks, independent of other main effects and interactions, was found on seven of the eight student computer outcome variables in the study. Five of these effects were of medium size and two were small. It should be noted that the time of the data collection was biased against the treatment. WiggleWorks students in the eighth month of the grade (April) were compared to nonWiggleWorks students in the ninth month of the grade (May).

In this study we used eta squared (proportion of the variance explained) as our indicator of effect size. In GLM eta squared is actually partial eta squared and it is unadjusted by sampling error. Hence it may over-estimate the proportion of the variance explained by each variable. We followed Kellow (1998) in defining as large, medium, and small effects, eta squared values of .25, .10, and .01, rather than the more generous definitions of .14, .06, and .01 of Cohen (1977). We recalculated the effect sizes using the procedures of Glass, McGaw, and Smith (1981) for the Hastings student results. We found that the gross effect sizes of WiggleWorks (i.e., without controlling for other independent variables) ranged from .44 to .83. When the seven significant effects were arranged in order of effect size magnitude the sequence was the same for the recalculated values as for the eta squareds produced by GLM, although two of the effects moved from medium to large effects when Glass et al.'s formula was used.

In addition to confirming these student benefits, the Peterborough data lent credence, in the second research questions, to the claim that the effects could be attributed to the interactive literacy software rather than to the novelty of the hardware, number of computers in the class or to student access to other software requiring a more powerful processor. Schools that received no new hardware were as likely to reap the benefits of WiggleWorks (in some instances more so) as schools that received new equipment. Although scores were higher in new than in old equipment schools on some measures, WiggleWorks had a greater impact (on student skill in tasks involving graphics and in student confidence in using computers) in old equipment schools. Although both groups of schools received the software and in-service training at the same time and experienced similar software-hardware interface problems, teachers and students in the old equipment schools had the advantage of an additional year of practice in working in a Windows environment.

There third question, concerning the moderating effects of gender and parent influence, generated unexpected findings. The effects of gender were few in number, small, and inconsistent. Males reported using computers more frequently than females (as expected) but females scored higher on word processing tasks in both districts and on basic computer literacy skills in Peterborough. There were no gender X program interactions, in contrast to studies that found that found that computer training reduced gender differences (Arch & Cummins, 1989; Levine & Donitsa-Schmidt, 1996; Siann et al., 1990; Torkzadeh and Koufteros, 1994). The weakness of gender in this study can be attributed to several factors. First, students in our sample were very young. Gender differences in computer outcomes tend to increase with age, intensifying in adolescence (Bannert & Arbinger, 1996; Comber, Colley, Hargreaves, & Dorn, 1997). Second, gender differences are larger in countries in which computing skills are taught exclusively by male teachers (Reinen & Plomp, 1997). That virtually all students in our study were taught by females meant there were female role models available to discourage stereotypical views of computing as a male activity. Females who believe that computing is a masculine domain underperform females who believe that computing is appropriate for both genders (Campbell; 1990; Nelson & Cooper, 1997; Ogletree & Williams, 1990). Third, the in-service strongly encouraged teachers to provide equal access to computing activities to all students, a prescription that was supported by norms of equity widely shared in both districts. Previous research has found that computer experience/use is a strong predictor of computer skill, confidence, and attitude (e.g., Carlson & Wright, 1993; Durndell, Macleod, & Siann, 1987; Gardner, Dukes, & Discenza, 1993; Geissler & Horridge, 1993; Koohang, 1989; Levin & Gordon, 1989).

Computer self-efficacy was higher in grade 2 in grade 1. This was somewhat unexpected because in other domains, self-efficacy declines with age: With greater experience and feedback from teachers, student self-inflations diminish (Wigfield, Eccles, & Rogriquez, 1998) and self-evaluations more closely match teacher judgments (Cole, Maxwell, & Martin, 1997). However, computer skills were also higher in grade 2 than in grade 1. The two results may indicate that students were accurately appraising their performance, perhaps because most students worked on WiggleWorks in groups (each class had only 3 or 4 licenses). Computer-based performance was relatively public. Students may have become more accurate because social comparisons were facilitated and peer feedback was available.

The study also found an unexpected interaction of the program with home environment. Children of parents who used computers (any use at home or work) scored higher overall on computer skills than children of nonusers but children of nonusers benefited more from WiggleWorks than children of computer-using parents. WiggleWorks training tended to compensate for lack of parental modeling of computer use, perhaps because of classroom norms of equality of access.

The fourth research question asked about teacher effects. The study found that WiggleWorks had a much smaller impact on teacher than student outcomes. But there were positive effects. After WiggleWorks teachers had higher expectations about their abilities to use a computer. This is an important result since previous research has found that teachers were reluctant to use computers in the classroom if they were uncomfortable with the technology (MacMillan et al., 1997). Studies of teacher efficacy (teacher confidence in their ability to bring about student learning) consistently demonstrate that teacher expectations about their ability vary by instructional context, predict teaching practice, and contribute to student achievement (reviewed in Ross, 1998). Teachers also spent more time assigning students to self-directed exploration of computer programs after WiggleWorks was introduced. Shifting the balance from teacher to student directed control of computers in learning has been cited as an indicator of more sophisticated instructional use of information technology (e.g., Sandholtz, Ringstaff, & Dwyer, 1997).

These results provide some support for the application of social cognition theory to teachers' experience with computers but it would be difficult to argue from our study that WiggleWorks had launched teachers on an upward spiral of successful experimentation with computer-based instruction, increased confidence in their ability to teach with computers, heightened use of computers or generated more positive attitudes to computers in the classroom. In addition, the findings are weakened by the research design for this component of the study: exposure to WiggleWorks was confounded with grade level preference. Although grade differences among Kindergarten-grade 2 teachers have not been investigated for computer outcomes, we cannot rule out the possibility.

The study also found interactions of WiggleWorks implementation with teacher characteristics. Teachers who did not own computers, unlike computer owners, experienced a decline in their confidence in using computers to teach in domains other than language, possibly because nonowners observed other teachers benefiting from practice at home. There were no differences between owners and nonowners in confidence in teaching with a computer in the language area because all teachers had the same opportunity for practice: The site license did not permit home use of WiggleWorks. The study also found that less experienced teachers benefited more than mature teachers from using the software. The confidence levels of the less experienced (teachers with under 20 years in the profession) increased on three of the four measures self-efficacy measures over the duration of the treatment. Yet there were virtually no changes on any of these measures for the more experienced. This finding differs from previous studies (reviewed by Dupagne & Krendle, 1992) that found that teaching experience had no consistent impact on teacher cognitions about computers.

The findings of this study are limited in several important ways. First, the data collection provided a snapshot of student performance taken before and after implementation. The snapshots were congruent with social cognition theory—there were changes in use, self-efficacy, skill, and attitudes—but a time series design would be required to demonstrate these changes occurred in the sequence predicted by the theory. Second, the ethical review committee in one of the districts prevented us from administering more salient measures of home environment. We were not permitted to obtain any indicator of social class, including whether or not there was a computer in the home. We suspect parental factors may be more powerful than our data indicate. Third, we had no measure of sextyping--a psychological construct indicating commitment to attributes socially characterized as masculine if male or to feminine attributes if female. Previous research (e.g., Ogletree & Williams, 1990) suggests that sextyping mediates gender differences in the cognitions of older students about computers. We suspect it influences younger ones as well. Fourth, as noted above, the teacher analysis confounded exposure to WiggleWorks with grade level preference. Fifth, there were too few males in the sample to investigate program X gender interactions.

Implications for Schools

Computer-based literacy programs are expensive. The cost of the software and the hardware to run it was almost $5,000 (US funds) per classroom in this project. The software licenses alone were $900 per classroom. Such a major expenditure is difficult to justify if the sole benefits are the small impacts on reading and writing performance reported in meta-analyses of computer-based literacy programs. The data in this study indicate that making WiggleWorks a central component of the grade 1-2 language program has important collateral benefits beyond its core functions. It contributes to student acquisition of computer skills essential to subsequent computer-based learning, it has a positive impact on student willingness to use computers to learn, and it contributed to increased teacher confidence in using computers. We regard the latter as especially important because computer phobia has its roots in the early experiences of children with computers (Gardner, Dukes & Discenza, 1995). This study demonstrates that the adoption of an interactive literacy program in the early years of schooling provides a solid cognitive and affective foundation for student access to information technology.

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Table 1 Means, Standard Deviations, and Reliabilities for Student Variables, 1997 and 1998, for Hastings and Peterborough

	Alpha	Hastings 1997 Means (n=196-221)	Hastings 1997 SD	Hastings 1998 Means (n=229-231)	Hastings 1998 SD	Peterborough 1997 Means (n=107-126)	Peterborough 1997 SD	Peterborough 1998 Means (n=107-126)	Peterborough 1998 SD
Student Computer Skills									
.keyboarding	.75	3.60	.50	3.82	.35	3.06	.68	3.68	.46
.basic computer literacy	.75	2.97	.78	3.50	.62	2.45	.72	3.37	.65
.word processing	.75	2.40	.76	2.70	.53	1.86	.71	2.69	.69
.software application	.73	2.53	.93	3.26	.71	2.04	.89	2.84	.97
.graphics	.62	2.34	1.07	3.23	.91	2.31	.86	3.28	.65
Computer Use	.75	2.11	.45	2.47	.34	1.92	.42	2.32	.36
Student Cognitions About Computers									
.enjoyment	.69	2.59	.34	2.64	.30	2.47	.45	2.56	.31
.self-efficacy	.80	2.20	.50	2.49	.40	1.84	.50	2.37	.37

Table 2 WiggleWorks Effects on Hastings Student Outcomes: Multivariate and Univariate Effects

Multivariate Effects	Student Computer Skills			Student Cognitions		
	$F(5, 415)$	p	eta^2	$F(2, 444)$	p	eta^2
Intercept	7079.22	.000	.99	18900.60	.000	.99
Year	27.23	.000	.25	26.51	.000	.11
Grade	8.80	.000	.10	11.42	.000	.05
Gender	1.65	.145	.02	1.97	.140	.01
Year x Grade	1.10	.361	.01	3.39	.035	.02
Year x Gender	.55	.741	.01	1.04	.355	.01

	Significant Univariate Effects (p<.05)			
	Year		Year x Grade	
	$F(1, 419)$	eta^2	$F(1, 419)$	eta^2
Student Computer Skills				
.keyboarding	31.33	.07		
.basic computer literacy	66.73	.14		
.word processing	25.02	.06	4.62	.01
.software applications	86.26	.17		
.graphics	87.35	.17		
	$F(1, 445)$	eta^2	$F(1, 445)$	eta^2
Student Cognitions About Computers			6.71	.02
.enjoyment				
.self-efficacy	52.92	.11		

Table 3 WiggleWorks Effects on Peterborough Student Outcomes: Multivariate and Univariate Effects

Multivariate Effects	Student Computer Skills			Student Cognitions		
	$F(5, 98)$	p	eta^2	$F(2, 120)$	p	eta^2
Intercept	1382.11	.000	.99	4990.80	.000	.99
Gender	2.20	.060	.10	2.61	.078	.04
Age	1.47	.208	.07	3.53	.032	.06
Equipment	1.68	.146	.08	9.39	.000	.14
Parent Computer Use	2.06	.077	.10	.81	.448	.01
Time	30.29	.000	.61	40.66	.000	.40
Time x Gender	.58	.715	.03	.92	.402	.02
Time x Age	.87	.506	.04	.98	.379	.02
Time x Equipment	11.08	.000	.36	.09	.917	.00
Time x Parent Use	2.97	.015	.13	1.40	.250	.02

Significant Univariate Effects ($p<.05$)

	Time		Time x Equipment		Time x Parent Use	
	$F(1, 102)$	eta^2	$F(1, 102)$	eta^2	$F(1, 102)$	eta^2
Student Computer Skills						
.keyboarding	87.77	.46			10.33	.09
.basic computer literacy	88.10	.46				
.word processing	49.98	.33				
.software applications	34.84	.26				
.graphics	71.13	.41	31.12	.23		
	$F(1, 121)$	eta^2				
Student Cognitions About Computers						
.enjoyment						
.self-efficacy	81.71	.40				

Table 4 Means, Standard Deviations, and Reliabilities for Teacher Variables in 1997 and 1998

	Alpha	1997 Means (n=69)	1997 SD (n=69)	1998 Means (n=69)	1998 SD (n=69)
Teacher Use of Computers					
personal computer use	.80	2.24	.92	2.73	.90
practice: exploration activities	.91	2.21	.77	2.59	.72
practice: direct teaching	.94	1.96	.73	2.00	.59
Teacher Efficacy Beliefs					
confidence: basic skills	.93	4.15	1.03	4.52	.61
confidence: advanced skills	.92	2.66	1.08	2.94	1.03
confidence teaching language uses	.84	4.32	.70	4.49	.61
confidence teaching other uses	.77	4.15	.83	4.18	.95
Teacher Attitude to Computers					
Attitudes to instructional use (a)	.76	4.10	.54	4.11	.54
attitudes to instructional use (b)	.85	4.16	.61	4.25	.63

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