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Designing technology for emergent literacy: The PictoPal initiative

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A B S T R A C T

PictoPal is the name of a technology-supported intervention designed to foster the development of emergent reading and writing skills in four and five year old children. Following the theoretical underpinnings and a brief description of PictoPal, this article describes how children worked with the technology; how the intervention elicited their engagement with literacy concepts both on the computer and off; and effects on early literacy learning. Observation results indicate that children are able to work independently with the program after a few instruction sessions. Observation data yield insight in the nature of adult guidance and the way the results of computer activities were implemented in off-computer classroom activities, as well as areas where this could be improved. Comparison of the four pre–post test experiments used to assess learning effects, suggest that the on-computer activities in PictoPal can yield a statistically significant learning effect, but only when integration with off-computer activities is present.

1. Introduction

In the Netherlands, interest in supporting the development of emergent literacy has been growing in the last decade (McKenney, Letschert, & Kloprogge, 2007). This is exemplified by the recent establishment of a national expertise center that aims to promote interactive Dutch language instruction, as well as increased funding for language programs, especially those targeting at-risk children in the 3–5 age bracket (e.g., Corvers, Aarnoutse, & Peters, 2004). The specification of language attainment targets for 4–6 year old children (Verhoeven & Arnoutse, 1999) further demonstrates the commitment to taking early language development seriously, yet many Dutch kindergarten teachers struggle to work with them. In the Netherlands and abroad, support tools have been created to help teachers make effective use of early literacy attainment targets (e.g., Bronkhorst, Paus, & Wentink, 1999; Daro, Hampton, & Resnick, 2004).

The study reported on here took place in the Netherlands, where most children attend both junior and senior kindergarten. Various language curricula are available for use among this age group, with Schatkist ("Treasure Chest") being among the most popular. National goals for early literacy (Verhoeven & Arnoutse, 1999) may be clustered into three main areas: (a) language consciousness, alphabetic principles, technical reading and writing; (b) book orientation, story understanding and reading and writing comprehension; and (c) functions of written language, relationship between spoken and written language, functional reading and writing. Previous research has examined the potential for software to offer added-value in learning alphabetic principles and the technical aspects of reading and writing (Segers & Verhoeven, 2002, 2005) as well as book orientation and story understanding (de Jong & Bus, 2003, 2004). This study examines how the computer can contribute to an understanding of the nature and function of written language. Doing so requires that attention be given to the relationship between spoken and written language and the purposes for which reading and writing are used. As in oral language learning, children's concept formation regarding written language is driven by its use, in an environment rich with meaningful messages and functional print (Van Scoter, 2008; Warash, Strong, & Donoho, 1999). The PictoPal learning environment was developed with the aim of fostering a better understanding of the nature and function of written language. The environment contains integrated on- and off-computer activities. The main question shaping this study was "How can the technology-supported learning environment, PictoPal, contribute to helping kindergarteners understand the nature and function of written language?"

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2. Theoretical foundations

2.1. Young children, play and linguistic concept formation

The study reported on in this paper derives its foundations from historically notable theorists on the development of young children, who have emphasized the notion that children have active roles in their own development (Bruner, 1983; Piaget, 1952; Piaget & Inhelder, 1969; Vygotsky, 1962). The work of Vygotsky (1978) considers the social situatedness of mind and cognition. Rooted in Vygotsky's theories, Bruner (1983) not only views the socio-cultural setting, but also regards specifically the behaviour of the child's entourage as crucial. In a similar vein, Macnamara (1972) views language learning as being driven by and dependent on the capacity to understand and participate in social situations. Central to this study is the notion that the formation of linguistic concepts (e.g., the nature and function of language), is fuelled by a child's innate desire to engage with the world, and the resulting interaction that ensues.

Play is the dominant medium for early childhood learning in many countries, and the Netherlands is no exception. It is generally accepted that play is an important means to help young children learn to participate in social settings and to develop their language abilities. In symbolic play (largely pretend play) children try out language uses as they to act on their environments (Piaget & Inhelder, 1969). Pretend play is, therefore, considered a valuable contributor to the development of early literacy (van Scoter, 2008), as it provides a vehicle through which children may satisfy their interests while communicating with others in ways that have personal meaning (Neuman & Roskos, 2005). When play activities are tied to authentic uses, the learning gains stand to increase (Leseman, Rollenberg, & Rispens, 2001). Credible evidence suggests that play can serve literacy development (Roskos & Christie, 2001) and this position has become widely supported by experts in the field (Kraayenoord & Paris, 1996; Neuman & Roskos, 2005). Roskos and Christie (2001) conducted a critical analysis of 20 recent investigations at the 'play–literacy interface'. They found that play can serve literacy in several ways, and their analysis on the use of literacy-related props in dramatic play settings indicated that print-enriched play settings contributed to large increases in emergent reading and writing activity during play. As artefacts, literary props can help children develop linguistic concepts related to the nature of written language (e.g., the conventional format for a postcard). When used in symbolic play, children are often experimenting with the linguistic function associated with the prop (e.g., sharing experiences with relatives while on vacation).

The National Association for the Education of Young Children (NAEYC) provides recommendations for developmentally appropriate practices in the domain of early literacy. NAEYC (1998, 2005) advocates that classroom environments include (among others): adults who engage in conversations, model reading and writing behaviours and foster children's interest in reading and writing; print-rich environments that provide opportunities and tools for children to see and use written language for a variety of purposes, as well as opportunities to engage in play that incorporates literacy tools (e.g., grocery list writing); and firsthand experiences that expand children's vocabulary, such as trips in the community and exposure to new artefacts. Neuman and Roskos (2005) additionally call for sustained and in-depth learning, including play; and a 'masterful orchestration of activity' (p. 3) that supports learning and social–emotional development. With young children, linguistic concepts are not developed in isolation, but rather through the uses of language that are elicited by engagement in a wide variety of – real and pretend – activities.

2.2. Technology and young children

The use of computers in early childhood educational settings is controversial. There are practical concerns, like these, "One computer in a kindergarten classroom is... about as useful as one container with three pencils when I have 27 children in a room," (Turbill, 2001, p. 275). There are worries about promoting a sedentary lifestyle and posing health hazards, "The risks include repetitive stress injuries, eyestrain, obesity, social isolation, and for some, long-term physical, emotional, or intellectual developmental damage," (Cordes & Miller, 2000, p. 3). And there are anxieties about tight budgets and decisions in which technologies are prioritized above books (Turbill, 2001). Skepticism has been met with guidelines on developmentally appropriate practice (NAEYC, 1996) as well as research programs into developmentally appropriate technology in early childhood, such as Developmentally Appropriate Technology in Early Childhood (DATEC) and Children's Awareness of Technology (CHAT) (cf. Brooker & Siraj-Blatchford, 2002).

Various studies have been conducted in technology use for early literacy development, such as Computer Aided Instruction (CAI) for reading (van Daal & Reitsma, 2000; Vernadakis, Avgerinos, Tsikori, & Zachopoulus, 2005), phonological awareness (Cassady & Smith, 2004; Mioduser, Tur-Kaspa, & Leitner, 2000; Segers & Verhoeven, 2005), vocabulary gains (Segers & Verhoeven, 2002; Segers, Verhoeven, Boot, Berkers, & Vermeer, 2001), and electronic storybooks (de Jong & Bus, 2004; Grimshaw, Dungworth, McKnight, & Morris, 2007). In Lankshear and Knoebel's (2003) review of research on technology use for early childhood literacy, the vast majority of studies dealt with receiving language (listening, reading); a few were marginally associated with writing or speaking; and no studies were found that share the focus of the PictoPal initiative: furthering linguistic concept formation regarding the nature and function of written language by producing and using texts.

A line of inquiry important for the PictoPal initiative regarding the use of technology in literacy development relates to the role of computers as catalyst for social interaction. Studies have shown that properly shaped collaborative use of the computer can contribute to pro-social behaviours, including: lively interactions, shared vocabularies, mutual enjoyment and spontaneous, active off-computer play (Brooker & Siraj-Blatchford, 2002; Clements, Nastasi, & Swaminathan, 1993; Haugland & Wright, 1997; Van Scoter, 2008). Pelletier, Reeves, and Halewood (2006) found that young children were capable of using technology as a social tool for knowledge building and that doing so contributed to literacy development as a beneficial by-product. Plowman and Stephen (2007) found that guided interaction by adults during computer activities fosters social interaction. However, they also noticed that reactive supervision is currently the most common form of adult guidance (Plowman & Stephen, 2005).

In accordance with the notion that it is meaning and use that drives language development and understanding of linguistic concepts, pro-social, language-eliciting behaviour is especially promoted when the computer offers children opportunities to create and use language (products) in authentic ways (Van Scoter, 2008; Voogt & McKenney, 2007). This calls for open learning environments on the computer that are integrated into off-computer activities as anchors for learning (Brooker & Siraj-Blatchford, 2002; Davis & Shade, 1994; Verhoeven, Segers, Bronkhorst, & Boyes, 2006). Such programs must therefore be designed with a working knowledge of young children's use of visual media in meaning-making, as studied by Turbill (2001) and Walsh (2003).

Realistic conceptions of computer practices and abilities of this age group are required; and research in this area is growing (Brooker & Siraj-Blatchford, 2002; Hill, 2004; Xiaoming & Atkins, 2004). Designers of educational software for use by junior and senior kindergarten children stress the need for features tailored to ergonomic needs of this age group, such as large buttons, oversized cursors, minimal need for "dragging" icons (Segers & Verhoeven, 2002). Usability testing must consequently be adjusted to the developmental abilities of the target audience (see Hanna, Risden and Alexander (1997) for guidelines). Simultaneously, attention must be given to potentially counterproductive features such as cued animations or sound effects that can provide inconsiderate distractions and have adverse effects on pupil concentration (Trushell & Maitland, 2005). In a similar vein, care must be taken when selecting hardware as some promote negative rather than positive collaborations; this has been the case with touch-screen technologies that allow children to pursue their individual goals as opposed to encouraging them to cooperate and achieve a common goal via one available input device (Romeo, Edwards, McNamara, Walker, & Ziguras, 2003).

Many software applications for early literacy development are isolated programs; few are attuned to desired pedagogical practices within kindergarten classrooms as a whole. For this reason, researchers mention the lack of pedagogical models underpinning many technology applications for use with this age range (e.g., Plowman & Stephen, 2003, 2005; Trushell & Maitland, 2005; Verhoeven et al., 2006). In the design of PictoPal, we aimed specifically toward realizing a technology-supported intervention, while also explicitly addressing integration with other developmentally appropriate, off-computer practices in the kindergarten. Speaking to the aforementioned void of research on production of texts in technology-supported early literacy research, the PictoPal intervention builds on principles of social interaction and meaning-making through its emphasis on generating real documents on the computer which are then used in dramatic play and/or authentic settings.

3. About PictoPal

3.1. Ideas underpinning PictoPal design

The PictoPal intervention was designed to help meet national interim goals for early literacy. The primary focus was on understanding the nature of written language. Secondarily, the program was designed to help children recognize (a) the relationship between spoken and written language; and (b) purposeful reading and writing. The use of technology in the PictoPal endeavor centers on writing and generating documents on the computer to be used either as literary props or for authentic purposes in the off-computer activities. Using technology in this way is consistent with Papert's (1980) ideas on constructionism, where children should be enabled to "learn by making".

The research presented in the previous section sculpted a pedagogically appropriate design of PictoPal. Four parameters guided the design of PictoPal:

- PictoPal should be an open learning environment that facilitates children's active role in creating written products which may be used for a variety of purposes and in authentic ways.
- PictoPal on-computer activities should elicit dialogue and collaboration, preferably with adults as well as peers.
- The products of PictoPal computer activities should be used in related off-computer activities, to promote print-enriched play and authentic use, and to encourage interaction and language use in meaningful social settings.
- The design of the PictoPal computer environment should be guided by usability testing so as to address the ergonomic needs of kindergarteners.

In addition to these guidelines and the theoretical foundations described above, three convictions are central to the design of the PictoPal intervention:

- Children want to express themselves in print, even before they are able to read.
- The powerful combination of images and print can help children to express themselves.
- The computer can offer added-value by helping children to focus on formulating their message rather than the mechanics of writing.

The component description below explains how the design guidelines ideas took shape.

3.2. PictoPal components

In the PictoPal project, pupils' language development and linguistic conceptual understanding are fostered through their interaction in three social settings: (a) collaboration while using the computer to compose written documents; (b) shared pretend play using printouts of the written documents as literary props (e.g., grocery lists to 'use' in the store corner; recipes for 'cooking' in the classroom kitchen) and (c) sharing printed work with a wider audience (e.g., letters to family are mailed; poems are read aloud at circle time).

Three versions of PictoPal were designed, evaluated and revised. All versions of the PictoPal learning environment contained on- and off-computer activities; the main differences are summarized in Table 1. The first version was created using Authorware®, subsequent prototypes made use of an existing tool: Clicker®. In addition to semi-open activities, the first version of PictoPal also contained closed activities through which the children could learn the pictogram vocabulary. After the first study, it became clear that no practice was necessary to facilitate understanding of the image–word relationship, so the closed items were discarded, and a wider range of pictograms was then deemed acceptable. Starting with the second prototype, the on-computer activities have made use of Clicker® software. Clicker® is a visual word processor; it allows children to click on images and/or words to type complete words at a time. Once the closed items were discarded, Clicker® was viewed as preferable because the production of new semi-open activities requires substantially less technical expertise. With Clicker®, teachers could be involved in the design of the semi-open activities. The duration of the first intervention was extremely short;

Table 1
Overview of the technology component of the three PictoPal prototypes.

	Version 1	Version 2	Version 3
Platform	Authorware®	Clicker®	Clicker®
Pictograms used	Black and white line drawings	Mixed forms of clip art	Mixed forms of clipart
Number of assignments	4	8	8
Type of assignments	Closed and semi-open	Semi-open	Semi-open
Topics addressed	Everyday activities	Houses	The weather
Support for children			Interactive agent

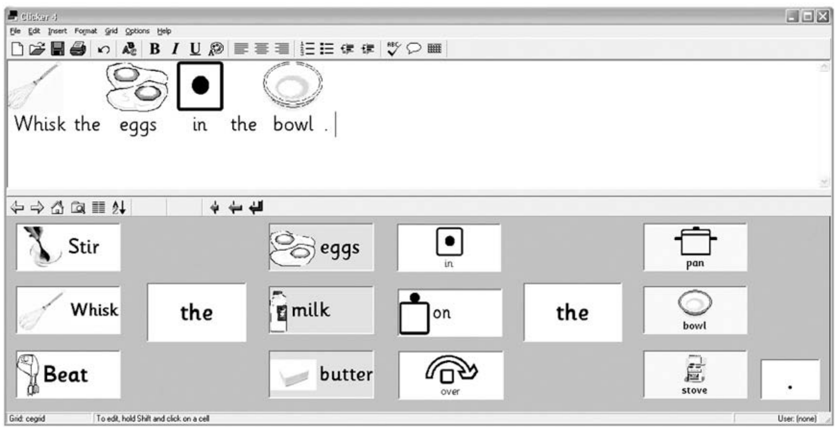

Fig. 1. Sample grid.

this was doubled in the second version and kept as such when more promising results were found in the second study. Each prototype addressed different themes, with coordinated on- and off-computer activities. The last prototype included modest use of an interactive agent.

Each semi-open on-computer activity features the creation of a particular text type (letter, poem, list, etc.). The documents resulting from computer use are then integrated with off-computer activities in the classroom (e.g., letters are mailed, poems read aloud, groceries 'bought' in the store corner, etc.). Fig. 1 shows a sample screen with two parts: the top shows the document being created; and the bottom (translated) Clicker® grid, allows the young users to create texts without typing or even being able to read. The two images in Fig. 2 demonstrate how children use the computer to generate meaningful texts (left), which are then printed and used in the classroom play corners (right).

4. Studies examining the effects of PictoPal

4.1. Research approach

The PictoPal inquiry may best be characterized as design research (cf. McKenney, van den Akker, & Nieveen, 2006), and thus also aimed toward explication of the ideas underpinning the design with the hope of contributing to knowledge building and helping other designers to generate ideas for use in their own settings (McKenney, 2008). Based on the findings from the literature review three prototypes were (re)designed and formatively evaluated. During the cyclic process of design, formative evaluation and revision of the three PictoPal versions, answers were sought to the following main question: "How can the technology-supported learning environment, PictoPal, contribute to helping kindergarteners understand the nature and function of written language?"

Fig. 2. Child with adult guide (here a student teacher) writing recipes (left); another cooking it all up (right).

Several characteristics in the technology's design warranted usability testing, as these were seen to be pre-requisites to being able to make meaningful use of the system. Therefore, before being able to answer the main research question, examination of learner abilities to work with the technology was needed. The importance of play and social interaction in the PictoPal intervention required examination of the function of guidance by adults and the implementation of off-computer activities in the classroom. Since PictoPal ultimately aimed to contribute to the development of early literacy, the nature and function of written language in particular, pupil knowledge and skills in this domain were also studied. In summary, data were collected in the following three domains throughout the research and development cycles:

(1) *Learner's ability to use the technology component of PictoPal:* mouse operation; comprehension of the computerized voice; and ability to work independently.
(2) *Eliciting engagement:* primarily related to function of adult guides and the implementation of off-computer activities in the classroom.
(3) *Literacy knowledge and skills:* primarily related to the functions of written language; secondarily related to the relationship between spoken and written language and purposeful reading and writing.

Four small scale studies were conducted during the design and evaluation of the three prototypes. Research assistants collected the data in each study. Three schools and eight teachers participated in the four studies on a voluntary basis. All pupils ($n = 172$) of these teachers participated in the study, either in the experimental or control condition. The on-computer activities took place in computer clusters, just outside the classrooms. The first two studies were very limited and aimed at exploring the potential of the PictoPal environment for early literacy development. The third and fourth studies were conducted on a somewhat larger scale. In these studies the implementation of the off-computer activities and the role of adult guidance were explored. Data collection and findings of the four studies are presented below.

4.2. Study 1

4.2.1. Focus

The first study reported here used the first prototype, PictoPal (v1). In this prototype, closed activities as well as semi-open activities were offered to the pupils. The closed activities were very structured and made use of pre-determined pictograms, which were also used in a common paper-based method (de Wit-Gosker, 1990). The activities emphasized recognition of the images and using them to 'read' sentences composed of pictograms. The semi-open activities were less structured. They focused on 'writing' and authentic applications in classroom practice. Although the children printed their products, this early evaluation format offered little opportunity to explore the engagement aspect of the off-computer activities. Study 1 focused on learner abilities to use the technology component of the PictoPal environment (1) and learner's gains in early literacy skills, particularly those related to the function and nature of written language (3).

4.2.2. Methods

Subjects: Kindergarten children from two schools were divided into experimental ($n = 21$) and control groups ($n = 19$), matched for age, gender, language skills (based on a national language test for kindergarteners) and remediation offered. One of each pair was randomly assigned to either the control or the experimental group. The experimental group worked with the PictoPal environment four times over a period of five weeks. One computer session took about 20 min.

Instruments: Pupils from the experimental group were observed during their PictoPal (v1) sessions. With the help of an observation checklist, the researcher charted whether children needed no, some or much assistance needed while working with the environment, in comprehending the computer voice and in operating the mouse. In addition, pre- and a post-test were given to the experimental and the control groups. The Early Literacy Skills Test was developed by the researchers and validated by an early language expert. The items were based on those standards for early literacy that focused on the nature and function of written language (Verhoeven & Arnoutse, 1999). The reliability of the test was acceptable (Cronbach's alpha = 0.85). The items were distributed proportionally to the main goals of PictoPal: nine items relate to functional reading and writing (using written language for communicative purposes); four items relate to functions of written language; two items pertain to the relationship between spoken and written language; and two items address language consciousness. Here are two examples:

- *Understanding text types (functional reading and writing):* When given a grocery list, a postcard, a cookbook and a picture book, children were asked to point to the postcard.
- *Distinguishing form from meaning (language consciousness):* Children were given corresponding animal picture–word combinations and told what words were written. Then they were asked to identify which word (not animal) is the biggest (an English example: the word mosquito is biggest, but the cow is the biggest animal in the set).

4.2.3. Results

The results, presented in Table 2, show that learners were able to work mostly independently with the program after some initial help. Kindergarteners possessed sufficient motor skills to use the mouse and with a brief introduction, they adjusted to the computer voice as well. After three to four sessions, most pupils were able to grasp the assignments and carry them out with little help. The effect size (Cohen's *d*) between sessions 1 and 4 showed that pupils particularly improved in their understanding of the semi-open assignments and in using the mouse when working with these assignments. This was encouraging because it also showed that pupils can learn to work independently with the less structured assignments, which is more challenging to implement (than structured assignments) but more in line with the goals of the intervention.

Table 3 presents the mean scores and standard deviations of the experimental and control group pre- and post-tests. To determine learning effects, the learning gain was calculated (learning gain is post- and pre-test scores). Both groups had a significant learning gain (control group $t(18) = -3.26$, $p = 0.004$; experimental group $t(20) = -3.17$, $p = 0.05$), as could be determined with a paired-*t*-test. Although

Table 2
Ability of experimental group pupils to independently understand the assignments and operate the mouse (Study 1).

	M(*SD*)				Effect size
	Session 1	Session 2	Session 3	Session 4	Sessions 1–4
Understands (closed assignments)	1.71(0.78)	1.81(0.68)	1.57(0.75)	1.33(0.66)	0.53
Understands (semi-open assignments)	2.14(0.57)	2.14(0.73)	1.90(0.77)	1.67(0.58)	0.82
Mouse use (closed assignments)	1.52(0.75)	1.38(0.67)	1.33(0.66)	1.24(0.54)	0.43
Mouse use (semi-open assignments)	2.00(0.63)	1.62(0.74)	1.71(0.72)	1.43(0.60)	0.93

Note: scored on a three point scale: 3 = needs a lot of help; 2 = needs a little help; and 1 = needs no help.

Table 3
Mean scores (*M*), standard deviation (*SD*) of pre- and post-test scores, learning gain and effect size on the Early Literacy Skills Test of the experimental and control group (Study 1).

	n	Pre-test *M*(*SD*)	Post-test *M*(*SD*)	Learning gain *M*(*SD*)	Effect size
Experimental condition	21	0.57(0.24)	0.65(0.25)	0.07(0.11)	0.30
Control condition	19	0.64(0.23)	0.70(0.20)	0.06(0.08)	0.28

the experimental group had a slightly higher learning gain, the effect size is about the same for both groups. After four computer sessions with PictoPal, no convincing evidence was found to indicate that the intervention improves emergent reading and writing skills. However, the results as shown in Table 2 also indicated that in the first study positive effects probably could not be confirmed, because of the short duration and incidental use of PictoPal. Further research was deemed necessary to study the effect of PictoPal when used more frequently and over a longer period of time.

4.3. Study 2

4.3.1. Focus

The findings from the first study had showed that pupils can learn to work with the semi-open assignments in PictoPal quickly. This implied that initial teacher investment would be needed but that it could fade after three to four sessions. Additionally, all participants (children, teachers and experts) agreed that the semi-open assignments featuring real-world applications were more interesting, motivating, challenging and meaningful. For these reasons the second version of PictoPal (v2) contained only semi-open assignments. The PictoPal (v2) activities for the second study were designed by the participating teacher together with the researchers and were related to a current classroom theme. In contrast to the extremely brief treatment in the first study, the number of PictoPal sessions was doubled. As in the previous study, a computer session took about 20 min. To address the need for adult guidance, the decision was made to explore the use of parent volunteers when the children used PictoPal. Videos were taken of the on- and off-computer activities, but no structured observations took place. Data were collected on learner gains in early literacy skills, particularly those related to the function and nature of written language (3).

4.3.2. Methods

Subjects: Kindergarten children from one school were divided into experimental ($n = 7$) and control groups ($n = 7$). As in the previous study, the pupils were matched for age, gender, language skills (based on a national language test for kindergarteners) and remediation offered. One of each pair was randomly assigned to either the control or the experimental group. The experimental group worked once a week with PictoPal, in total eight times.

Instruments: The Early Literacy Skills Test was slightly revised (Cronbach's alpha = 0.87) and administered to pupils from the experimental and control group before and after the treatment.

4.3.3. Results

Table 4 presents the mean scores and standard deviations of the experimental and control group. A large learning gain was found for the experimental group. Using the Mann–Whitney *U* test, a significant difference in learning effects was determined for the experimental versus the control group ($Z = -2.256$, $p < .024$). The effect size for the experimental group was considerably higher compared to the control group. After eight computer sessions with PictoPal, evidence was found to indicate that the PictoPal intervention improves emergent reading and writing skills. However, it must be noted that the experiment was very small and conclusions have therefore a limited meaning. For this reason follow-up studies with a larger number of children was conducted (Studies 3 and 4).

4.4. Study 3

4.4.1. Focus

The third study was conducted with the third version of PictoPal (v3). The new theme was created to tie into the school-wide thematic science month on weather. In this study, the experimental group worked with PictoPal computer activities, while the control group used an

Table 4
Mean scores (*M*), standard deviation (*SD*) of pre- and post-test scores, learning gain and effect size on the Early Literacy Skills Test of the experimental and control group (Study 2).

	n	Pre-test *M*(*SD*)	Post-test *M*(*SD*)	Learning gain *M*(*SD*)	Effect size
Experimental condition	7	0.68(0.20)	0.96(0.21)	0.27(0.64)	1.36
Control condition	7	0.55(0.31)	0.60(0.24)	0.05(0.20)	0.18

alternative language program: 'Kijken en Kiezen' ('Look and Choose'). Kijken en Kiezen was designed by the author of the pictogram set described in the first PictoPal prototype, and uses those same images to introduce children to written language. As in the second study, pupils in the experimental group were engaged in eight PictoPal computer activities of 20 min each. Similarly, control group children had eight computer sessions of 20 min. As in the second study, parents were available to elicit dialogue and interaction during the on-computers activities of PictoPal, but no structured observations on how parents coached the children were carried out. The main focus of this study was a first exploration of the implementation of the off-computer classroom activities. The learner's products resulting from the PictoPal computer activities were printed and used in classroom applications. Six observations, of 15–25 min each, have been carried out in two kindergarten classrooms. In the classroom activities, children from the experimental and from the control group participated. In Study 3, data were collected on teacher's use of and students' attitudes towards the off-computer activities (2) and on learning gains in early literacy skills, particularly those related to the function and nature of written language (3).

4.4.2. Methods

Subjects: 79 junior and senior kindergarteners from one elementary school (new in the study) participated. The pupils were matched in the same way as in the previous studies. One of each pair was randomly assigned to either the control ($n = 39$) or the experimental group ($n = 40$). Two teachers were observed, while they were implementing the products of PictoPal computer activities in the classroom.

Instruments: An off-computer observation scheme was developed in which brief open descriptions could be noted related to seven areas: teacher enthusiasm; intensity of the class activity; teacher-made connections between on- and off-computer activities in the class; organization of the activities; teacher literacy-consciousness; behaviour of learners who did and who did not use PictoPal computer activities. The Early Literacy Skills Test was also used (Cronbach's alpha = 0.65) and administered to pupils from the experimental and control group before and after the treatment.

4.4.3. Results

A paired-*t*-test has been used to analyze the differences in learning gain between the experimental and the control group. The results are presented in Table 5. The experimental group had a significantly higher learning gain compared to the control group (experimental group: $t(39) = -2.65$, $p = 0.01$); control group: $t(38) = 0.00$, $p = 1.00$). The effect size for the experimental group (0.41) was considerably higher compared to the control group (no effect).

The observation results of the off-computer activities (see Fig. 3) indicate that teachers grew in their role. In the first lessons they were awaiting and classroom organization was messy. In later lessons, organizational matters faded to the background, and teachers seemed much more able to connect on- and off-computer activities and to relate the activities with early literacy goals. Also the children had to get used to their new roles initially. The users of PictoPal computer activities (pupils of the experimental group) felt unsure about what was expected from them in the first lessons but a steady growth in confidence and enthusiasm was observed. Among the observers (those who did not create documents themselves, because they were part of the control group), interest and curiosity grew with each session.

4.5. Study 4

4.5.1. Focus

The fourth study was also conducted with PictoPal (v3), and centered on the role of the adult guides during PictoPal computer sessions. As in the third study the experimental group worked with PictoPal computer activities, while the control group used an alternative language program ('Kijken en Kiezen' – 'Look and Choose'). There were eight computer sessions for the experimental and control group; each session took about 20 min. During eight weeks, parents coached 4–5 children from the experimental group during the 20-min computer sessions. The parents encouraged dialogue and interaction related to the computer assignments by asking questions such as "what did you write?" Data collection in this study focused on adult guidance (2) and on learner's gains in early literacy skills, particularly those related to the function and nature of written language (3).

4.5.2. Methods

Subjects: The study was conducted with 37 junior and senior kindergarteners from the same school that participated in the second study, but with different children. The same matching procedure as applied in the other studies was used resulting in an experimental group of 19 and a control group of 18 children. In addition, four parents participated in the study. These parents were asked by the teacher to volunteer as an adult guide. Children from the experimental group were each week randomly assigned to an adult guide.

Instruments: The on-computer adult–child interaction observation scheme was based on an instrument created by Damhuis, de Blauw, and Brandenbarg (2004). With the observation scheme, data on adult–child interaction were scored as not present, sometimes present and regularly present with regard to: creating the necessary conditions for engagement (e.g., a safe learning climate and the desire to communicate); providing language offerings (e.g., speaking clearly and correctly, helping children articulate themselves); creating space for active participation in a conversation (e.g., leaving silences unfilled, giving verbal and non-verbal responses); stimulating linguistic development (e.g., elaborating on what children contribute, introducing more complex linguistic functions); and offering feedback (e.g., implicit corrections, summarizes). As in the other studies the Early Literacy Skills Test was used (Cronbach's alpha = 0.77) and administered to pupils from the experimental and control group before and after the treatment.

Table 5
Mean scores (*M*), standard deviation (*SD*) of pre- and post-test scores, learning gain and effect size on the Early Literacy Skills Test of the experimental and control group (Study 3).

	n	Pre-test *M*(*SD*)	Post-test *M*(*SD*)	Learning gain *M*(*SD*)	Effect size
Experimental condition	40	0.79(0.15)	0.85(0.14)	0.06(0.14)	0.41
Control condition	39	0.81(0.14)	0.81(0.12)	0.00(0.17)	0.00

		Early lessons	Middle lessons	Later lessons
Teacher behaviour	Enthusiasm	• Reserved with regard to the on-computer activities • View classroom applications as obligations	• Are very enthusiastic about the products and radiate enthusiasm toward the children • Quote: "Now you may send this lovely postcard all by yourself!"	• Teachers radiate enthusiasm while classroom applications flow smoothly • New ideas for applications are being considered
	Intensity	• Much time is devoted to the PictoPal activities • Teacher indicates desire to be (extra) well-prepared for the first lessons	• Due to busy days, less time is devoted to applications in the classroom	• Teachers allow much freedom and space for pupils' own creativity • In both groups, things take longer than planned
	Link on-off computer	• Teachers make no link with the on-computer activities	• A relationship is between the on- and off-computer activities is consciously created • Quote: "Please tell us what you have done on the computer"	• Teachers both begin the lesson with recapitulation of the computer activities
	Organization	• Due to good preparation, the lessons flow smoothly • Organisation is geared toward the interim objective of creating a product, with seemingly little attention for the terminal objectives	• Messy lessons due to the type of assignments and moderate preparation	• Lessons flow 'without a hitch' • Teachers appear more accustomed to the pedagogical approach where products are made on the computer and used in the classroom
	Early literacy awareness	• Teachers are very busy with the organization and appear to have lost sight of the main goals • It is notable that the teachers are very busy with the final products • No visible evidence of attention to the interim goals for early literacy are present	• The various functions and of written language are clearly addressed during the sessions • Teachers still seem focused on the product (this time, a postcard)	• Teachers work with the interim goals for early literacy in a visible way • Teachers emphasize the relationships between written words, related pictograms and the meanings • Teachers use different conversational situations to stimulate language use and pupil thinking
Pupil behaviour	Non-PictoPal	• Learners are distracted, because the lessons are messy • Some children would like to do something else	• Since all children made a postcard, they are all engaged • Circle time takes too long for some of the children	• Learners listen and actively participate in the circle time conversation • Learners enjoy listening to the letters that are read aloud
	PictoPal users	• Learners are not clear on what they are supposed to do nor why • Quote: "But, you know I can't read?!" •	• Attitude is very positive • Learners get turns in circle time and appear to enjoy making postcards	• Learners elaborated on their self-made stories • Learners were elated about their self-made letters

Fig. 3. Summary of observation results (Study 3).

4.5.3. Results

With a paired-*t*-test the differences in learning gain between the experimental and the control group have been determined. In this study a significant higher learning gain of the control group was found compared to the experimental group (experimental group: $t(18) = -4.28$, $p = 0.674$); control group: $t(17) = -3.03$, $p = 0.007$). The effect size for the control group is 0.53, and much higher than the effect size in the experimental group. The results are presented in Table 6.

Although the findings of the first pilot study suggest that pupils may be able work independently with PictoPal, developmentally appropriate practice suggests that some degree of adult guidance is preferable during the on-computer activities, to encourage dialogue and interaction. In the fourth study structured observations were conducted to help understand the nature of the interactions as well as to learn about where to target potential training for adult guides, only technical (not pedagogical) instruction was given prior to use with the children. Four adult guides were observed during eight computer sessions with PictoPal. As illustrated by the summary in Fig. 4, it appeared that adults were able to create a safe climate and room for active involvement of pupils in the conversation. The four adults differed in the kind of feedback they gave to the pupils with two of them providing various forms of feedback. Most of the adults (except one) had difficulties in interacting with pupils aiming at encouraging quality: continuation/expansion of a topic, negotiation of meaning and initiating

Table 6
Mean scores (*M*), standard deviation (*SD*) of pre- and post-test scores, learning gain and effect size on the Early Literacy Skills Test of the experimental and control group (Study 4).

	n	Pre-test *M*(*SD*)	Post-test *M*(*SD*)	Learning gain *M*(*SD*)	Effect size
Experimental condition	19	0.77(0.10)	0.78(0.14)	0.01(0.95)	0.08
Control condition	18	0.63(0.19)	0.72(0.15)	0.92(0.13)	0.53

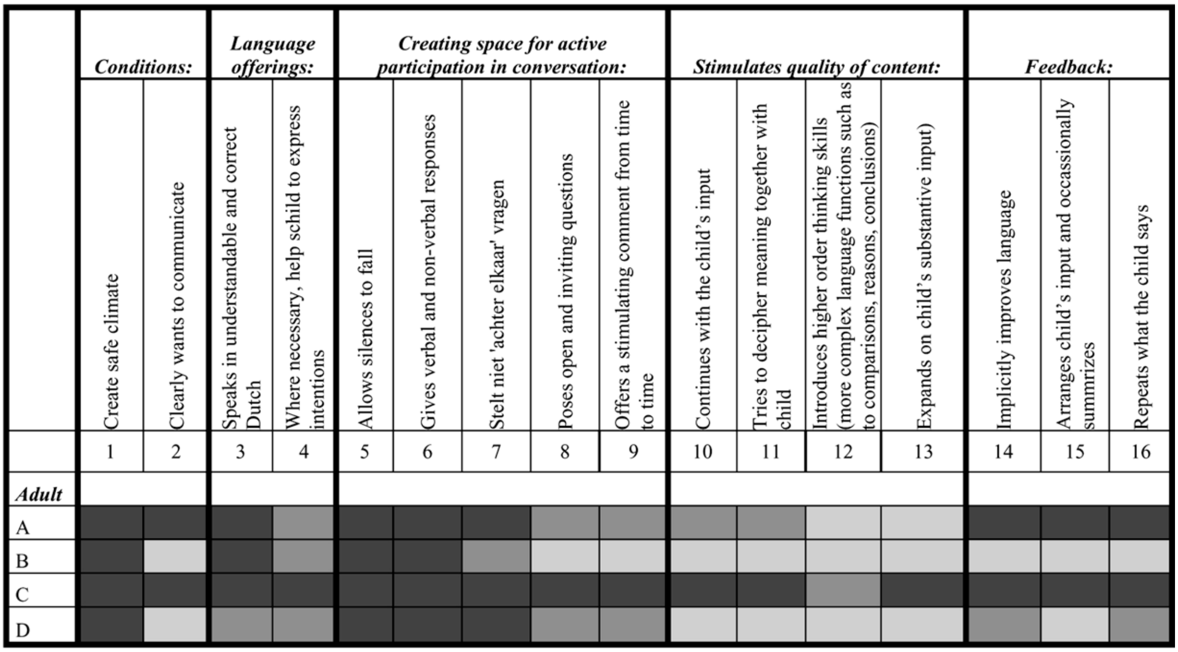

Fig. 4. Averaged observations for the parent–child interaction.

reflection and higher level of language use. While all four adults created space for active participation, only one of them regularly posed open questions and offered stimulating comments.

5. Discussion and conclusions

This study sought to understand how PictoPal could contribute to fostering early literacy. In so doing, three areas were examined: learner abilities to use the technology, pupil engagement and literacy learning; the first two being viewed as pre-requisites for the latter. The findings of the first study demonstrate that kindergarteners are able to use the technology independently, after initial coaching. The second study mainly dealt with setting up a system of adult guides to promote dialogue and interaction during the on-computer activities of PictoPal. Pupil engagement was more systematically studied in Studies 3 and 4. Two levels of engagement were explored: the implementation of off-computer activities (Study 3) and the role of adult guidance (Study 4). Both were important components of the design of the PictoPal intervention. In all four studies, children's literacy knowledge and skills regarding functions of written language were addressed.

The off-computer learner engagement data from Study 3 suggests that it takes three or four sessions before the activities become enough of an organizational routine and the students find their way sufficiently to allow the engagement with the content to blossom. A problem in the third study was of course that about half of children had not been actively involved in the creation of documents, because they were part of the control group. Further, more in-depth research about the implementation of off-computer activities in a more natural classroom setting (i.e., without experimental-control groups) would be useful to better understand the function of on- and off-computer activities in the learning process of the children. The implementation of off-computer activities might also be easier when on- and off-computer activities are better linked to current classroom themes. This could particularly be realized if teachers are involved in the design of PictoPal on- and off-computer activities.

The findings of the fourth study suggest that untrained adults had difficulties in interacting with pupils aiming at encouraging quality, particularly related to higher levels of language use. To be able to elicit dialogue and interaction, a clear need for training was observed. Next, teachers preferred pupils' independent work with the computer activities in PictoPal because of the extra burden they experienced in arranging for adult guides. However, such an approach would fail to use the computer interactions as a catalyst for social interaction, as previously described. With this goal in mind, it would seem worth considering the value of pairing older and younger children and giving them clear roles in collaboration.

The pre- and post-test learning data are inconclusive, as two of the four studies showed that significant learning gains were made. The main difference between those studies and the two where no significant learning gains were made was the integration of off-computer activities in the classroom. This suggests that using the products of the on-computer activities for authentic purposes and dramatic play in the classroom is essential to fostering pupil learning. This explanation would concur with current views that literacy development is driven by meaning-making (Neuman, Copple, & Bredekamp, 2000; Warash et al., 1999). However, because of the limited scope of the study with regard to the relation between computer activities and integrated classroom activities, further research is necessary to verify or deny this explanation.

The overarching question driving the PictoPal studies was, "How can the technology-supported learning environment, PictoPal, contribute to helping kindergarteners understand the nature and function of written language?" Based on the findings and discussion, several conclusions may be drawn. First, the technology-supported learning environment, PictoPal, can contribute to understanding the function of written language when pupils are provided with guidance for at least the first few sessions, facilitating the development of the technology skills necessary to use the software. Additionally, PictoPal can contribute to eliciting learner engagement during on-computer sessions; this should be further stimulated by a guide (older child or adult). Untrained guides tend to naturally stimulate conversation, but are less inclined to promote further engagement with the content. Off-computer activities also elicit learner engagement, but without support, teachers need several sessions for this aspect to develop. Finally, use of the PictoPal system can lead to gains in literacy knowledge and skills, but probably only when integration with off-computer activities is present.

Interpreting the findings from the four studies should not be undertaken without understanding the strengths and limitations of the research approach. Four main areas bear mention: the limited depth of implementation; the limited scope; the fact that all four research assistants also contributed some degree of project facilitation; and variation in adult guidance. All the four studies were conducted as extra projects on a trial basis. As such, the research assistants assisted in PictoPal implementation by helping with software installation and serving as resources for teachers and adult guides during PictoPal sessions. Studying innovations that are undertaken as trial projects introduces at least two biases that may balance each other out, but cannot be ignored: temporary bouts of enthusiasm and energy on behalf of teachers which might not be sustainable over the long-term; and more organizational and possibly even conceptual fumbling than would likely be the case once the activity structures have been internalized by the teachers. Finally, a potential confounding effect due to interaction with different adult guides may have influenced the children's literacy scores.

Based on the findings so far, several areas of research to further develop the PictoPal intervention can be identified. First, further examination of the best way to realize integration of on- and off-computer activities in classroom practice seems necessary to better understand how the PictoPal intervention can support the learning of kindergarteners. Because the teacher plays a crucial role in the successful integration of both activities, it seems useful to focus further research on the way the teacher can best be supported in how to integrate the on- and off-computer activities. While guided interaction (Plowman & Stephen, 2007) by adult guides may seem impractical for many teachers, guided participation (Rogoff, 1990) – featuring collaboration with a more skilled partner – could be more practical. Rogoff's (1990) concept of guided participation is an effort to extend Vygotsky's notion of the "zone of proximal development". In guided participation, children and their partners manage activity with varying degrees of asymmetry and use overt as well as tacit communication to build bridges from their current understanding to reach new understanding. For the PictoPal intervention this implies that further research is needed about how dialogue fostering language use in pairs of junior and senior kindergarteners could be elicited, e.g., in the form of additional scaffolds that would help empower children to work collaboratively and independently as they learn language while creating written documents.

Because the integration of on- and off-computer activities is crucial to the PictoPal intervention, it seems prudent to continue PictoPal research and development in the setting of natural classrooms, using quasi-experimental research designs. Closer cooperation with teachers could be beneficial for a better integration of on- and off-computer activities in PictoPal, because they could be involved in the design of these activities. After all, teacher involvement in curriculum design strengthens feelings of ownership with the PictoPal intervention and would contribute to curriculum implementation (cf. Ben-Peretz, 1990; Clandinin & Connelly, 1992). Such an approach will result in more in-depth knowledge of factors that influence the implementation and the efficacy of the PictoPal intervention. It may also speak to the need for examples of how to shape the technical and pedagogical support to teachers implementing technology-rich language learning environments (Labbo et al., 2003; Verhoeven et al., 2006). After that, up-scaling the PictoPal intervention and research in large scale studies seems appropriate.

The PictoPal research and development effort offers one approach to fostering the development of emergent literacy skills. While research at the crossroads of technology and early literacy is growing (Van Scoter, 2008), the current knowledge base is still limited (Lankshear & Knoebel, 2003). With its focus on using technology to write and generate meaning, as opposed to reading, the PictoPal endeavor is truly innovative. Although the conclusions from these studies may only be taken as tentative, it would seem that further inquiry is warranted to better understand the possibilities offered by this unique learning environment.

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