

Information and communication technology reading interventions: A scoping review



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Background: Information and communication technology (ICT) reading interventions can help children with reading difficulties, especially those in resource-constrained environments who otherwise might not have support.

Objectives: (1) Provide an overview of ICT reading interventions used globally with primary school children. (2) Provide further information on the subset of studies conducted in majority world countries, describing the interventions used, their impact on reading and challenges faced.

Method: A scoping review was used with a search strategy that yielded a total of 49 studies for inclusion in the main review (Objective 1), and a subset of five studies undertaken in the majority world (Objective 2).

Results: Most published studies (93.88%, 46 studies) demonstrated positive outcomes of ICT reading interventions on learners' reading. Well-researched programmes with demonstrated effectiveness included GraphoGame, ABRACADABRA, Reading RACES and Chassymo. Only five studies (10.2%) were conducted in the majority world, but all reported in this subset described positive literacy gains through ABRACADABRA and GraphoGame.

Conclusion: There is a growing evidence base of ICT reading interventions that could be helpful in addressing the reading crisis in South Africa. Programmes such as ABRACADABRA and GraphoGame demonstrate effectiveness in a variety of contexts and may have a role to play in addressing the reading challenges faced by children in South Africa.

Contribution: The review highlighted evidence supporting the use of ICT reading interventions. Evidence of such approaches in South Africa (and other majority world countries) remains limited and requires further evaluation of both existing and innovative, locally developed interventions.

Keywords: reading interventions; ICT; computer-based; applications; effectiveness.

Introduction

The majority of South African learners are not developing the reading skills expected for each grade when compared to their international peers (Department of Basic Education 2014; Mullis et al. 2017). This is a multifaceted problem linked to a complex interplay of educational, political, social and economic factors described by authors such as Spaul (2013). Factors related to learners' underperformance include resource constraints, inadequate teacher training, poor instructional practices, low parental literacy levels, learning in a second or additional language, and high rates of absenteeism (Howie et al. 2017). Multifaceted interventions that focus on a range of aspects such as infrastructure, teacher training and classroom interventions are necessary to address the situation and bring about a more positive outlook.

In this article we focus specifically on interventions for learners with reading difficulties, based on our backgrounds as speech-language therapists (SLTs) working to support learners with literacy and language challenges. Speech-language therapists play an important role in promoting the communication and literacy development of children and providing evidence-based intervention to at-risk individuals. However, SLTs comprise a small professional group in South Africa, culturally and linguistically appropriate resources are scarce, and most SLTs working in the public sector are employed by health rather than education departments. There is thus an urgent need for innovative approaches to help SLTs increase their reach (Nadler-Nir & Pascoe 2016).

Large-scale, population-based interventions are required to target reading in South African schools. In their evidence-based profession, it is important for SLTs to know which interventions

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have demonstrated effectiveness, as well as to expand the evidence base through ongoing intervention studies.

Reading intervention research shows that targeting phonological awareness, phonics, fluency, vocabulary and reading comprehension in an explicit, intensive and systematic manner improves reading skills (Galuschka et al. 2014; Gibson & Musti-Rao 2017; National Reading Panel 2000; Suggate 2016). Despite this knowledge, serving the large population of children requiring reading intervention is a challenge, especially in resource-constrained contexts. One approach to providing reading support is through the use of information and communication technology (ICT) programmes. There is a wide range of technology-based tools available to help children develop their reading, spelling and language abilities. These vary in terms of the ages targeted, their specific focus, platforms used, accessibility and cost. Although not all studies investigating the impact of ICT-based approaches to reading have reported positive outcomes (Campuzano et al. 2009), reviews and meta-analyses indicate that many ICT programmes produce gains in phonological awareness, phonics, word reading, fluency, vocabulary and reading comprehension of school-aged children (Cheung & Slavin 2011, 2013; Jamshidifarsani et al. 2019; Moran et al. 2008). Information and communication technology-based reading intervention holds potential for improving the reading skills of children by harnessing their motivation to learn through feelings of autonomy (making choices), competence (achieving goals), and relatedness (sharing experiences with another individual), providing immediate feedback and having the capacity to be intensive, individualised, and at the appropriate level of difficulty, and enabling independent use or the presence of non-professionals (McTigue & Uppstad 2018).

In this scoping review we set out to describe ICT interventions for reading and their outcomes as described in the literature. A particular aim of the study was to consider interventions developed for, or investigated in the majority world (developing) contexts which might offer solutions to the challenges faced in South Africa.

The objectives of the study were to: (1) provide an overview of ICT-based reading interventions described in the literature over the last decade (2009–2019) and (2) consider the subset of ICT reading interventions conducted in the majority world and their impact on learners' reading skills and challenges faced, which could lead to recommendations for research conducted in similar contexts, such as South Africa.

Methodology

Scoping reviews are used to map the main sources and types of evidence available, and are particularly useful when an area is complex or has not been reviewed comprehensively before. Arksey and O'Malley's (2005) framework has five steps: (1) identifying the research question or aim. This review set out to describe ICT reading interventions for primary school learners undertaken in the last decade.

In particular we wanted to know what work has been undertaken in the majority world so that we could investigate programmes reported to be effective in this context and build on them further. (2) Identifying and (3) selecting relevant studies. A search strategy, criteria for eligibility and study selection were devised, and are described in the following sections. (4) Data are then charted, collated and (5) reported in the results section of the article. The search took place between June 2018 and June 2019, undertaken mainly by the first author with the other two authors in a checking and support role. To ensure a valid and reliable process, measures were put in place such as team briefings on a regular basis to discuss any uncertainties regarding the process and findings to date.

Search strategy

First, a pilot phase was initiated in which one database was searched using a set of core terms. Titles, keywords and index terms taken from this initial set of papers were then used to develop the list of search terms further. Second, following the pilot phase, researchers then used the complete search term list with the full set of electronic databases. Keywords were entered into the electronic databases of PsycArticles, PsychINFO, ERIC, Computers and Applied Sciences Complete, Academic Search Premier and CINAHL.

The keywords were: information and communication technology; computer-assisted; computer-based; laptop; smartphone; iPhone; tablet; iPad; application; programme; software; reading intervention; reading instruction; reading therapy; reading remedial; primary school; elementary school; middle school; junior school; children and learners.

Eligibility criteria

Studies were included in the review based on the following inclusion criteria:

- Published in a peer-reviewed journal between 2009 and 2019.
- Interventions described needed to be delivered by ICT, and aimed at improving reading or reading-related skills (one or more of the components of phonological awareness, letter-sound knowledge or phonics, word reading, fluency, vocabulary and reading comprehension).
- Learners in Grades 1 to 7 were the participants.
- Experimental or quasi-experimental designs were used, that is, the included studies all considered the effect of an intervention on particular outcomes; control groups were used, although in the case of a quasi-experimental design assignment into the groups was not random.

Due to time and resource constraints we were only able to access and review papers in English, and grey literature (e.g. postgraduate student projects, government reports) was not searched. Meta-analyses, reviews and editorial or discussion pieces were excluded. We wanted to access original research papers that might have contributed to a

meta-analysis or review, or informed a discussion piece. We aimed to access original research where full methodological information and results could be accessed. Titles and abstracts of papers generated by the search were reviewed by the team.

Study selection

The first author screened the titles and abstracts of the articles from the electronic search, and then read full texts of all papers that met the eligibility criteria. Papers were excluded when the eligibility criteria were not met. If a full-text article could not be accessed, it was automatically excluded from the database. A total of 49 studies met the inclusion criteria and were subsequently included in the review.

Data collection

After identification of relevant papers, full-text articles were read and data extracted from them. Detailed information about resources was charted in a spreadsheet including the name of the paper, authors, journal, country in which the study took place, research design, number and nature of participants, the name or description of intervention, devices used, outcomes measured, person supporting the intervention, and summary of outcomes. To ensure reliable reporting, the second and third authors cross-checked a proportion (20%) of all entries into the database.

Results

Overview of ICT-based reading interventions described in the literature

In the 49 papers included in this part of the study, the most commonly used design was an experimental pre-post design with random assignment to groups at the level of schools, classes or learners (23 studies; 46.94%) and experimental multiple baseline design across participants (10 studies; 20.4%). There were 27 (55.1%) studies where ICT interventions were compared to a control group receiving no intervention and 16 (32.65%) studies that evaluated ICT interventions against other interventions. Sample sizes varied widely with most studies (29/49, 59.2%) having fewer than 100 participants. Of the studies that described the grade of the participants, most focused on children in Grades 1 to 3. Most (40/49; 81.6%) had both male and female participants. The studies included learners with different characteristics such as: at risk of having reading difficulties (7; 14.29%), reading difficulties (26; 53.1%), language difficulties (3; 6.12%), and learners from mainstream schools not included based on any identified difficulties (13; 26.53%). Five studies included learners with additional difficulties (such as intellectual disability, attention deficit and hyperactivity disorder, autism spectrum disorder and learning disability). Of the studies that reported the language characteristics of the participants, 29 investigated monolingual children, 9 involved bilingual children and 4 worked with bi- and monolingual children. Many studies did not report on the languages of the participants.

A total of 46 different ICT reading interventions were described. Some studies evaluated one programme while others used two or more, comparing outcomes between groups. Programmes used in more than two studies included *GraphoGame/GraphoLearn* (henceforth *GraphoGame*) (used in 10 papers), *ABRACADABRA* (6 papers), *Reading RACES* (3 papers) and *Chassyimo* (3 papers). These 'big four' programmes thus dominated the literature for the time period investigated. *GraphoGame* targets multiple levels of reading (phonics and letter-sound knowledge, phonological awareness and word reading). It is a theoretically informed intervention that has been well researched over many years and adapted for use in a variety of different languages. The programme is available to all school-aged children in Finland, and in many other countries around the world in adapted forms (see Ojanen et al. 2015 for further information).

ABRACADABRA similarly targets a range of skills including phonics and letter-sound knowledge, word reading, reading and listening comprehension, reading fluency and meta-cognition in reading and writing. It was developed in Canada and has been extensively used there as well as in Australia. It is based on the recommendations of the National Reading Panel (2000) and includes a variety of different activities tailored to children's specific abilities and challenges. *Reading RACES* focuses on oral reading fluency through a repeated reading strategy using culturally relevant stories for primary school children. *Chassyimo*, developed in French, focuses on the syllable as the main processing unit in reading and requires learners to hear or read syllables in a carefully programmed presentation. Most of the other interventions targeted two or more skills, such as reading fluency and comprehension (e.g. Bennett et al. 2017) while a smaller number focused solely on one particular skill such as sight-word reading (e.g. Musti-Rao, Lo & Plati 2015), or reading comprehension (e.g. Ponce, López & Mayer 2012).

Interventions were delivered in various languages, although English dominated (30 studies, 61.22%). Of the studies that described the language background of the learners, there were 30 where the intervention was in the participants' home language, 6 where the intervention was in the participants' second language, 2 where the intervention was in the first and second language and 4 where the language of intervention was some participants' home language but other participants' second language. A total of 18 different countries were represented. Almost half of the papers were from US-based studies (21 papers) and other countries that were well represented included France (4), England (3), Sweden (3), and Canada (3).

The devices used to deliver intervention mainly included computers (35; 71.42%) and iPads or tablets (10; 20.4%). There was a balance between studies that required facilitation (25; 51.02%) and those in which learners worked independently (22; 44.89%). When intervention was facilitated this was most typically done by trained teachers. Intervention intensity varied across studies with reported

total intervention time ranging from 50 min to 109 h. The mean length of total intervention time was 16 h typically undertaken in half-hour blocks delivered two to three times per week. Most studies (29, 59.18%) used standardised outcome measures. Some used non-standardised outcome measures (13, 26.5%) and the remainder used a combination of both standardised and non-standardised outcome measures. The number of studies that found intervention effects for their outcome measures was calculated. There were three studies that did not demonstrate effects on any outcome measures, nine that demonstrated effects on 15% – 50% of outcome measures, five that showed effects on 60% – 75% of outcome measures and 27 that showed effects on all outcome measures. There were five studies where the findings could not be categorised into these groups.

Therefore, of the studies that could be clustered into these groups, the vast majority (41/44; 93.18%) demonstrated some form of positive effect of ICT reading intervention on learners' reading and reading-related skills and most (32/44; 72.73%) showed improvements on 60% – 100% of outcome measures. Table 1 shows a mapping of the 49 papers to give an overview of the designs used, sample sizes and participants, intervention and outcomes. Further detail for each of the 49 papers is provided in the appendices (Tables 1-A1–3-A1).

Results from the first part of the study indicated a substantial number of ICT interventions for reading that have been researched and published in peer-reviewed journals over the past decade. Most of the programmes demonstrated positive

TABLE 1: Design and participant characteristics of studies included in the information and communication technology-based reading intervention scoping review.

Design and participant characteristics		Number of studies		Examples
		<i>n</i>	%	
Study design	Experimental pre-post with random assignment	23	46.94	O'Brien, Begum and Onnis (2019); Messer and Nash (2018); Patel et al. (2018); Solheim et al. (2018); Baker et al. (2017).
	Experimental multiple baseline across participants	10	20.41	Council et al. (2019); Mize et al. (2019); Barber et al. (2018); Musti-Rao et al. (2015); Lindeblad et al. (2016); Ozbek and Girli (2017).
	Other experimental design or quasi-experimental	16	32.65	Lysenko et al. (2019); Kleinsz et al. (2017); Mak et al. (2017); Moser, Morrison and Wilcox (2017).
Sample sizes	0–49	23	46.94	Council et al. (2019); Mize et al. (2019); Barber et al. (2018); Patel et al. (2018).
	50–99	6	12.24	Messer and Nash (2018); Baker et al. (2017); Van de Ven et al. (2017); Tyler et al. (2015).
	100–499	14	28.57	O'Brien et al. (2019); Mak et al. (2017); Abrami et al. (2016); Schneider et al. (2016).
	500–999	4	8.16	Solheim et al. (2018); Madden and Slavin (2017); Jere-Folotiya et al. (2014).
	1000 +	2	4.08	Lysenko et al. (2019); Ponce et al. (2012).
Participant grades	Grade 1	14	28.57	Barber et al. (2018); Solheim et al. (2018); Baker et al. (2017); Musti-Rao et al. (2015).
	Grade 2	10	20.41	Council et al. (2019); Bennett et al. (2017); Kleinsz et al. (2017); Schneider et al. (2016).
	Grade 3 upwards	6	12.24	Mize et al. (2019); Patel et al. (2018); Moser et al. (2017); El Zein et al. (2016).
	Mixed or not indicated	19	38.77	Lysenko et al. (2019); O'Brien et al. (2019); Madden and Slavin (2017).
Intervention	GraphoGame	10	20.41	O'Brien et al. (2019); Patel et al. (2018); Solheim et al. (2018); Baker et al. (2017); Kamykowska et al. (2014); Kyle et al. (2013).
	ABRACADABRA	6	12.24	Lysenko et al. (2019); Mak et al. (2017); Abrami et al. (2016); Lysenko and Abrami (2014); Savage et al. (2010).
	Reading Races	3	6.12	Council et al. (2019); Barber et al. (2018); Bennett et al. (2017).
	Chassymo	3	6.12	Kleinsz et al. (2017); Ecalle, Kleinsz and Magnan (2013)
	LoCo Text	2	4.08	Kleinsz et al. (2017); Potocki, Ecalle and Magnan (2013)
	Read 180	2	4.08	Kim et al. 2010, 2011.
	Tutoring with Alphie	2	4.08	Madden and Slavin (2017); Chambers et al. (2011).
	Omega-interactive sentences	2	4.08	Fälth et al. (2013); Gustafson et al. (2011).
	COMputerized PHOnological Training	2	4.08	Fälth et al. (2013); Gustafson et al. (2011); Mize et al. (2019); Messer and Nash (2018); Horne (2017); Moser et al. (2017); Ozbek and Girli (2017); Van de Ven et al. (2017).
Other	17	34.69		
Facilitation	None/independent	22	44.90	O'Brien et al. (2019); Barber et al. (2018); Messer and Nash (2018).
	Adult supported	24	48.98	Lysenko et al. (2019); Council et al. (2019); Bennett et al. (2017); Madden and Slavin (2017); Larabee, Burns and McComas (2014).
	Peer supported	1	2.04	Mize et al. (2019); Chambers et al. (2011).
	Mix of different supports	2	4.08	
Total intervention time	Up to 4 h	8	16.33	Mize et al. (2019).
	5 h – 25 h	14	28.57	Kleinsz et al. (2017); Ecalle et al. (2013); Fälth et al. (2013); Kyle et al. (2013).
	26 h – 50 h	3	6.12	Lysenko et al. (2019).
	More than 50 h	5	10.20	Saine et al. (2011); Torgesen et al. (2010).
Not reported	19	38.70	Mak et al. (2017); Schneider et al. (2016).	
Outcomes measures found to have changed significantly as a result of intervention	No outcomes measures shown to have changed; no intervention effect	3	6.12	Baker et al. (2017); Moser et al. (2017); Kamykowska et al. (2014).
	All outcomes measures changed; positive intervention effect	27	55.10	Council et al. (2019); Lysenko et al. (2019); Mize et al. (2019); O'Brien et al. (2019); Barber et al. (2018); Messer and Nash (2018); Solheim et al. (2018); Bennett et al. (2017); Kleinsz et al. (2017); Madden and Slavin (2017); Lindeblad et al. (2016).
	Mixed outcomes: Some show no change and others indicate positive effect	19	38.70	Patel et al. (2018); Horne (2017); Mak et al. (2017); Abrami et al. (2016); Schneider et al. (2016); Musti-Rao et al. (2015); Larabee et al. (2014).

Note: Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.

effects on children's literacy and language, despite variation in the nature and duration of the programmes. A small set of programmes (*GraphoGame*, *ABRACADABRA*, *Reading RACES*, and *ChassyMo*) appeared in multiple studies and seem to have been most rigorously investigated in the 10-year period to demonstrate their effectiveness in different contexts. Given our specific context and challenges in South Africa, the second part of the review focused on a subset of studies from the main scoping review, ICT interventions undertaken in majority world countries, which we considered might be especially applicable to children in South Africa.

ICT reading interventions conducted in the majority world and their impact on learners' reading skills

In the main data set we found five studies conducted in the majority world: two in Kenya, and one in each of Zambia, India and Tanzania, constituting 10.2% of the total number of papers found in the review. These five studies used two interventions from the 'big four' group introduced in the previous section: *ABRACADABRA* and *GraphoGame*. All studies conducted in the majority world demonstrated improvements in learners' reading skills as a result of the ICT intervention. Two of the studies found positive intervention effects on all outcome measures and three noted positive intervention effects on at least half of their outcome measures. Table 2 provides an overview of these studies.

Lysenko et al. (2019) conducted a study in Kenya that examined the effect of English *ABRACADABRA* intervention (targeting phonological awareness, phonics, word reading, fluency, vocabulary, listening comprehension, reading comprehension and writing) and READS intervention (online stories and books available in English and Kiswahili to improve reading fluency and comprehension) on English literacy skills. A quasi-experimental design was used with a large sample ($n = 1672$) of Grade 1–3 children learning English as a second language in mainstream schools. Schools were non-randomly assigned to ICT intervention or control conditions. Trained teachers facilitated intervention for a total of 2 h per week for a total of 16 weeks. Standardised assessments of English oral language and reading skills as well as participants' national examination results (in English, Social Studies, Mathematics and Science) were used as outcome measures. The results showed that intervention participants significantly outperformed control participants

on all measures. Another study using *ABRACADABRA* was undertaken by Abrami et al. (2016) in Kenya to investigate the impact of English *ABRACADABRA* intervention on mainstream Grade 2 children ($n = 354$) learning English as a second language. An experimental pre-test-post-test design with random assignment of classes to conditions (intervention versus no intervention or control) was used.

Intervention participants made significant gains in reading comprehension and listening comprehension compared to the control group and participants in the intervention group significantly outperformed children in the control group in the national examinations.

Ngorosho (2018) conducted a study in Tanzania that investigated the impact of Kiswahili *GraphoGame* (targeting phonological awareness, phonics and word reading) on Kiswahili literacy skills. An alternating treatment design with random assignment of schools to groups (ICT intervention versus non-ICT classroom intervention versus no intervention or control) was used. Participants were Kiswahili home language Grade 1 learners ($n = 49$) with poor reading skills. Participants accessed *GraphoGame* via smartphones and worked independently (without adults being involved in instruction) for three sessions per day, 10 min per session, 5 days a week (a total of 2–4 h of intervention). Non-standardised outcome measures were used. The findings indicated significant improvements for both the ICT and non-ICT classroom intervention, although the ICT intervention led to the greatest improvement. Jere-Folotiya et al. (2014) conducted a study in Zambia to determine the effect of ciNyanja *GraphoGame* on mainstream Grade 1 ($n = 573$) children's ciNyanja literacy skills. As for the Tanzanian study, learners accessed intervention independently on smartphones 3–5 days per week (for six sessions which were 7–9 min long per day) for a total of 1 h and 34 min of intervention. Standardised measures of orthographic awareness and spelling acted as outcome measures. The results showed that the intervention improved the spelling (intervention participants significantly outperformed control participants) but not the orthographic awareness of participants. The learners who were exposed to intervention directly (played *GraphoGame*) and indirectly (teacher played *GraphoGame*) produced significant improvements in spelling compared to control learners.

Patel et al. (2018) conducted a study in India using an experimental pre-test-post-test design with random

TABLE 2: Information and communication technology studies carried out in the majority world – An overview based on a subset of the main scoping review.

Study	Design	Participant characteristics			
		n	Grade	Age (years)	Selection criteria for inclusion
Lysenko et al. (2019)	Two-group, non-equivalent, pre-test-post-test quasi-experiment	1672	1–3	-	Mainstream learners
Ngorosho (2018)	Alternating treatment	49	1	7–9	Poor reading and spelling skills
Patel et al. (2018)	Pre-test and post-test, random assignment to groups	30	3	7–8	Reading difficulties, English second language learners
Abrami et al. (2016)	Pre-test and post-test (random assignment to intervention and control groups)	354	2	-	Mainstream learners
Jere-Folotiya et al. (2014)	Pre-test and post-test (random assignment to intervention and control groups)	573	1	5–9	Mainstream learners

Note: Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.

assignment to conditions (ICT reading intervention versus an ICT Mathematics intervention control). Grade 3 learners ($n = 30$) with reading difficulties who did not have English as a home language but were attending a school where English was the medium of instruction participated. Intervention participants used English *GraphoGame* (to improve phonological awareness, phonics and word reading) independently on tablets for 8 weeks (20–30 min per session and six sessions per week). Non-standardised (informal in-game assessments) and standardised literacy assessments were used as outcome measures. Significant improvements in favour of the intervention group were found for all *GraphoGame* in-game measures but there was no difference between the improvements of the intervention and control groups on the standardised measures. These interventions are summarised in Table 3.

The five studies conducted in the majority world (Abrami et al. 2016; Jere-Folotiya et al. 2014; Lysenko et al. 2019; Ngorosho 2018; Patel et al. 2018) reported a range of study-related challenges: learners had limited exposure to technology before beginning the intervention, high rates of learner absenteeism, learners arriving at school late, finding time for supplemental ICT intervention in a curriculum-determined timetable, lack of linguistically and culturally appropriate assessment measures (and lack of standardisation of assessments on the study population), technological issues, and venue constraints (no quiet venues at schools where intervention and assessments could be conducted). They reported the following contextual challenges: poor infrastructure, shortage of reading and teaching materials, poor working conditions for teachers, teachers inadequately trained for literacy instruction, poor teaching methods (rote learning), learners not being exposed to the language of learning and teaching in the home environment, parents having low literacy levels or being

illiterate, and lack of learner exposure to literacy activities in the home environment.

Discussion

Research conducted in the last decade suggests that ICT approaches to reading intervention can lead to improvements in learners' reading skills, and thus offers potential for providing support to large numbers of children who require it – especially in places such as South Africa which has an acknowledged literacy crisis (Spaull 2013). There were only four studies in the scoping review that were conducted in Africa and none of these was conducted in South Africa. However, the small subset of papers from the majority world tentatively suggest that ICT-based approaches to reading intervention may be helpful for improving the reading skills of children in settings with a similar socio-economic status and achievement profile to ours. The review highlights a gap in research that should be addressed due to the potential positive impact ICT reading interventions could have in such contexts.

Speech and language therapy is an evidence-based profession so professionals recommending or facilitating ICT literacy interventions will need to know which interventions have been shown to be effective, and the extent of the evidence. Some of the interventions in this review have been researched in many studies including other countries in Africa. We described the 'big four' ICT interventions emerging from the review which were *GraphoGame*, *ABRACADABRA*, *Reading RACES* and *Chassymo*. They are starting to emerge as programmes that could be considered for at-scale intervention in South Africa. In particular *GraphoGame* and *ABRACADABRA* have been used in many different contexts, including majority world countries. *GraphoGame* has been successfully adapted into

TABLE 3: Information and communication technology studies carried out in the majority world – Summary of interventions in the scoping review.

Study	Skills targeted in activities	Mode of delivery	Facilitator	Dosage	Outcomes
ABRACADABRA					
Lysenko et al. (2019)	Phoneme-grapheme knowledge and phonics, phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension and writing	Computer	Trained teachers	16 weeks 2 h per week	Statistically significant difference between experimental and control groups (in favour of the experimental group) on measures of word reading, vocabulary, reading and listening comprehension. Experimental participants significantly outperformed control participants in examinations.
Abrami et al. (2016)	Phoneme-grapheme knowledge and phonics, phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension and writing	Computer	Trained teachers	13 weeks 2 h per week	Intervention group made significant gains in reading and listening comprehension compared to control group. Medium effect sizes were found. No significant difference between the groups on other norm-referenced measures. Children in the intervention group outperformed children in the control group in their exams.
GraphoGame					
Ngorosho (2018) (Kiswahili GraphoGame)	Phoneme-grapheme knowledge and phonics, phonological awareness and word reading	Cell phones	Learners independent	3 sessions per day 10 min per session Five days per week Total intervention 2–4 h	Significant improvement for both GraphoGame and classroom instruction; GraphoGame had more improvement than classroom instruction.
Patel et al. (2018) (GraphoLearn)	Phoneme-grapheme knowledge and phonics, phonological awareness and word reading	Tablet	Learners independent	8 weeks 20–30 min per session 6 sessions per week	Significant differences in favour of the intervention group for all GraphoLearn in-game measures. No significant differences between the groups for standardised measures.
Jere-Folotiya et al. (2014) (ciNyanja GraphoGame)	Phoneme-grapheme knowledge and phonics	Cell phone	Learners independent	7–9 min sessions 6 sessions per day 3–5 days containing sessions per week 94 min (M) total intervention	The intervention improved the literacy skills of the participants (intervention learners significantly outperformed control learners).

Note: Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.

many languages and this adaptation would be particularly important for its use in South Africa too. Here it would be important for the programme to be adapted into learners' home languages, as well as second or additional languages because in Grade 4 there is a shift from mother tongue instruction to English or Afrikaans instruction in schools. Care would need to be taken to ensure cultural and linguistic appropriateness, but the effective adaptation and use in Zambia and Tanzania suggests that adaptation would be feasible. Home language interventions could be used to scaffold the development of English or Afrikaans language and literacy skills. The review found only a few studies with bilingual participants, which does not reflect the high international rates of childhood bilingualism (Paradis, Genesee & Crago 2011). There is also a great need for interventions to be developed specifically for bilingual learners and for their efficacy to be determined.

Although the potential of interventions such as *GraphoGame* for South Africa is clear, it is not to say that this intervention works better than other interventions. Rather it has been researched more and the process of evidence generation is more advanced than for some other programmes. The relative cost effectiveness and efficiency (ease of implementation) of each approach would need to be examined further so that the approaches with the strongest evidence and feasibility for implementation are selected at schools. Evidence-based practice refers to interventions and their application in particular contexts with particular individuals. Thus, interventions that are designed and tested in a particular setting with a group of children with particular characteristics may not be appropriate or effective for another setting or group of children. The use of established interventions would also not preclude the urgent need to develop and trial our own local interventions that may ultimately prove to be as effective.

South Africa has one of the highest mobile phone penetrations in the world (Ojo 2018) and therefore the use of smartphone-based interventions for improving both health and education is relevant. The two *GraphoGame* studies undertaken in Africa involved children using smartphones to access the intervention, and this approach may be worth considering further. During the COVID-19 pandemic when South Africa's schools were closed many children had no access to learning materials or any sort of educational support.

Smartphone-based apps such as *GraphoGame* could enable children to develop their reading skills anywhere and anytime, especially if the relevant apps were freely available and access to the data was zero-rated. Although findings related to intervention intensity and facilitation did not reveal clear patterns related to their relative effectiveness, studies with four to five sessions per week produced more widespread improvements than those with one to three sessions per week.

The studies conducted in the majority world reported a number of challenges associated with intervention delivery. Information and communication technology-based reading intervention studies conducted in similar contexts should

provide training to learners on how to use technological devices and provide opportunities for learners to become familiar with the devices before intervention commences. Smartphones are likely to be familiar to many children, but they may not be able to have access to their own device and may not be able to bring it to school. Innovative solutions to venue constraints such as having multiple intervention slots where only a few learners attend an intervention at each time, rearranging furniture and using classroom dividers, and dividing learners into groups may need to be considered in schools – highlighting a need for addressing basic infrastructure, which remains problematic in many South African schools. There is an urgent need to develop culturally and linguistically appropriate reading, teaching and assessment materials together with training opportunities related to how resources can be used. Workshops for teachers that focus on effective literacy instruction, and for parents who have low literacy levels related to how they can support their children's literacy learning, will also be valuable and should be seen as part of a broader solution to addressing challenges that an ICT intervention alone will not be able to address.

The scoping review may present a biased impression of the effectiveness of ICT interventions as studies demonstrating no effect are less likely to be published (Djulfbegovic & Guyatt 2017). Our review was also limited in that we only focused on a 10-year period and did not consider studies that were published in languages other than English and that used non-experimental methods. A systematic review or meta-analysis that seeks to address more specific questions about ICT reading interventions would be helpful, along with further studies that trial and evaluate ICT interventions in the majority world where they are most needed.

Conclusion

The scoping review described the characteristics of 49 ICT-based reading intervention studies for primary school children, published in the past decade. Findings indicate a promising range of different ICT-based interventions, most of which demonstrate positive outcomes although wide-ranging outcomes measures and research designs have been used. Only a small proportion of the studies were undertaken in the majority world. There is a great need for further work in this context and in particular in South Africa where reading outcomes are poor. It is clear that ICT-based approaches to reading intervention can lead to improvements in learners' reading skills, but further research is needed to determine if any of these interventions could be relevant for South African learners or to guide the development of innovative ICT-based interventions responsive to the needs of South African children and educators.

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Authors' contributions

J.D., M.P. and J.I.R. contributed to the design and implementation of the research, to the analysis of the results and to the writing of the article.

Ethical considerations

This article followed all ethical standards for carrying out research.

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Disclaimer

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Appendix 1

TABLE 1-A1: Design and participant characteristics of studies included in the information and communication technology-based reading intervention scoping review.

Study	Design	Participant characteristics					
		<i>n</i>	Grade	Age (years; months)	Sex	Language background	Difficulty
Council et al. (2019)	Multiple baseline across participants	5	2	7;5 (M)	M+F	Monolingual	At risk of reading difficulty
Lysenko et al. (2019)	Pre-test and post-test, quasi-experimental, non-random assignment by school	1672	1–3	-	M+F	Bilingual	None
Mize et al. (2019)	Multiple baseline across participants	4	5	10–11	M+F	Monolingual	Reading difficulty
O'Brien et al. (2019)	Pre-test and post-test, matched participants randomly assigned to intervention groups	148	1–2	6;7 (M)	-	Bilingual	At risk of reading difficulty
Barber et al. (2018)	Multiple baseline across participants	3	1	7;3 (M)	M+F	Bilingual	At risk of reading difficulty and special education
Messer and Nash (2018)	Pre-test and post-test, random assignment by learner	78	-	7;5 (M)	M+F	Monolingual	Reading difficulty
Ngorosho (2018)	Alternating treatment, random assignment by class	49	1	7–9	M+F	Monolingual	Reading difficulty
Patel et al. (2018)	Pre-test and post-test, random assignment by learner	30	3	7–8	M+F	Bilingual	Reading difficulty
Solheim et al. (2018)	Pre-test and post-test, random assignment by school	744	1	6;2 (M)	M+F	Monolingual	At risk of reading difficulty
Baker et al. (2017)	Pre-test and post-test, random assignment by class	78	1	-	M+F	Bilingual	None
Bennett et al. (2017)	Multiple baseline across participants	7	2	7;8 (M)	M+F	Monolingual	Reading difficulty
Horne (2017)	Pre-test and post-test, matched participants randomly assigned by learner	38	-	8;10 (M)	M+F	Monolingual	Reading difficulty
Kleinsz et al. (2017)	Pre-test and post-test, quasi-experimental, non-random assignment by learner	44	2	-	-	Monolingual	Reading difficulty
Madden and Slavin (2017)	Pre-test and post-test, random assignment to intervention and control groups by school	872 (study 1) 736 (study 2)	1–3	-	-	-	Reading difficulty
Mak et al. (2017)	Pre-test and post-test, quasi-experimental, non-random assignment by school	249	1	-	-	Bilingual	None
Moser et al. (2017)	Pre-test and post-test, quasi-experimental, non-random assignment by learner	29	4	-	M+F	Monolingual	None
Ozbek and Gırlı (2017)	Multiple baseline across participants	3	3–4	8–9	M+F	Monolingual	Reading difficulty
Van de Ven et al. (2017)	Pre-test and post-test, alternating treatment	69	-	8;8 (M)	M+F	Monolingual	Reading difficulty
Abrami et al. (2016)	Pre-test and post-test, random assignment by class	354	2	-	M+F	Bilingual	None
El Zein et al. (2016)	Alternating treatment, multiple baseline across participants	3	4–6	10;4 (M)	M	-	Reading difficulty, Autism spectrum disorder (ASD)
Lindeblad et al. (2016)	Multiple baseline across participants	35	4–6	10–12	M+F	Monolingual	Reading difficulty
Schneider et al. (2016)	Pre-test and post-test, random assignment by school	170	2	-	-	Some monolingual, some bilingual	None
Musti-Rao et al. (2015)	Multiple baseline across participants	3 (study 1) 3 (study 2)	1	6;3–7;9	M+F	Bilingual	At risk of reading difficulty
Shannon et al. (2015)	Pre-test and post-test, random assignment by class	344	1–4	-	M+F	Monolingual	None
Tyler et al. (2015)	Pre-test and post-test, random assignment by learner	51	2	6–7	M+F	Some monolingual, some bilingual	None
Jere-Folotiya et al. (2014)	Pre-test and post-test, random assignment by class	573	1	5–9	M+F	Monolingual	None
Kamykowska et al. (2014)	Alternating treatment, random assignment	62	1	6;3–7;4	M+F	Monolingual	None
Larabee et al. (2014)	Multiple baseline across participants, alternating treatment	3	1	6	M+F	Some monolingual, some bilingual	Reading difficulty
Lysenko and Abrami (2014)	Pre-test and post-test, quasi-experimental, non-random assignment by class	351 (study 1) 166 (study 2)	1–2	-	M+F	Monolingual	None
Rivera et al. (2014)	Alternating treatment, multiple baseline across participants	1	-	10;0	M	Bilingual	Reading difficulty, intellectual disability

TABLE 1-A1 continues on the next page →

TABLE 1-A1 (Continues...): Design and participant characteristics of studies included in the information and communication technology-based reading intervention scoping review.

Study	Design	Participant characteristics					
		<i>n</i>	Grade	Age (years; months)	Sex	Language background	Difficulty
Walcott, Marett and Hessel (2014)	Multiple baseline across participants	3 (study 1) 3 (study 2)	1 (study 1) 2 (study 2)	6–7 (study 1) 8–9 (study 2)	M+F (study 1) M (study 2)	Monolingual	Reading difficulty
Cullen, Keesey and Alber-Morgan (2013)	Multiple baseline across participants	4	4	-	M+F	Monolingual	Reading difficulty (additional difficulties: 2 with learning disabilities, 1 with intellectual disability and 1 with attention deficit and hyperactivity disorder).
Ecalte et al. (2013)	Pre-test and post-test, random assignment by learner	27 (study 1) 18 (study 2)	2 (study 1) 1 (study 2)	7;6 <i>M</i> (study 1) 6;6 <i>M</i> (study 2)	M+F	Monolingual	Reading difficulty
Fälth et al. (2013)	Pre-test and post-test, random assignment by learner	130	2	-	M+F	Monolingual	Reading difficulty
Heikkilä et al. (2013)	Pre-test and post-test, random assignment by learner	150	2–3	9;2	M+F	Monolingual	Reading difficulty
Kyle et al. (2013)	Pre-test and post-test, matched subject, random assignment of matched groups	31	2	6	M+F	Monolingual	Reading difficulty
Potocki et al. (2013)	Pre-test and post-test, random assignment by learner	30	2	7;6–7;7 (<i>M</i>)	-	Monolingual	Language difficulty
Ponce et al. (2012)	Pre-test and post-test, quasi-experimental, non-random assignment by school	1041	4	-	M+F	-	None
Chambers et al. (2011)	Pre-test and post-test, random assignment by school	(33 schools)	1–2	-	M+F	-	Reading difficulty
Gustafson et al. (2011)	Pre-test and post-test, random assignment by learner	130	2	-	M+F	Monolingual	Reading disability
Kim et al. (2011)	Pre-test and post-test, random assignment by learner	312	4–6	10;5 (<i>M</i>)	M+F	-	Language difficulty
Saine et al. (2011)	Pre-test and post-test, random assignment by learner	166	1	7	M+F	Monolingual	At risk of reading difficulty
Yaw et al. (2011)	Multiple baselines across participant	1	6	12	M	Monolingual	Reading difficulty, ASD
Kim et al. (2010)	Pre-test and post-test, random assignment by learner	294	4–6	-	M+F	-	Language difficulty
Savage et al. (2010)	Pre-test and post-test, quasi-experimental, non-random assignment by class	60	1	6;5–7;1 6;5 (<i>M</i>)	M+F	Monolingual	None
Torgesen et al. (2010)	Pre-test and post-test, random assignment by learner	112	1	6;6 (<i>M</i>)	M+F	Monolingual	At risk of reading difficulty
Ecalte, Magnan and Calmus (2009)	Pre-test and post-test, random assignment by learner	28	1	6;10 (<i>M</i>)	M+F	Monolingual	Reading difficulty
Macaruso and Rodman (2009)	Pre-test and post-test, random assignment by class	47	6–7	-	M+F	-	Reading difficulty
Savage et al. (2009)	Pre-test and post-test, random assignment by class	144	1	6;8 (<i>M</i>)	M+F	Some monolingual, some bilingual	None

Note: Papers are ordered chronologically by year and alphabetically within years. Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.

n, sample size; M, mean; M, male; F, female; + indicates 'and'; -, information could not be found in the article.

TABLE 2-A1: Characteristics of the interventions included in the information and communication technology-based reading intervention literature review papers.

Study	Name or description	Language of intervention	Language of intervention child's first (L1) or second (L2) language	Skills targeted in activities	Mode of delivery	Facilitator	Dosage
Council et al. (2019)	Reading RACES (Relevant and Culturally Engaging Stories)	English	L1	Reading fluency and reading comprehension	Computer	Trained paraprofessional	School year 3–4 sessions per week 25–30 min per session
Lysenko et al. (2019)	ABRACADABRA and READS	English and Kiswahili	Both	Phonics; phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension and writing	Computer	Trained teachers	16 weeks 2 h per week
Mize et al. (2019)	K12 Timed Reading Practice and peer-assisted reading instruction	English	L1	Reading fluency	iPad	Peers	22 sessions 4–5 sessions a week 12 min per session
O'Brien et al. (2019)	Intervention Phase 1: Phoneme and Rime level See Word Reading Word level: Matching words with pictures; selecting correct spelling; reading words aloud Intervention Phase 2: GraphoLearn – Phoneme GraphoLearn – Rime Word level: Matching sentences with pictures; reading sentences aloud	English	L2	Phonics and letter-sound knowledge accuracy Word reading Phonics and letter-sound knowledge fluency Sentence reading	iPad	Learners independent	All groups 7 weeks per phase (total 14 weeks of intervention) 10 min sessions 5 sessions per week Total of 28 sessions
Barber et al. (2018)	Reading RACES	English	L2	Reading fluency and reading comprehension	Computer	Learners independent	7–11 weeks 1–4 sessions per week 20–30 min per session
Messer and Nash (2018)	Trainertext	English	L1	Phonics and phonological awareness and decoding	Computer	Learners independent	10 months 2–3 sessions per week 10–15 min per session
Ngorosho (2018)	Kiswahili GraphoGame	Kiswahili	L1	Phonics and phonological awareness and word reading	Cell phones	Learners independent	3 sessions per day; 10 min per session; Five days per week Total: 2–4 h
Patel et al. (2018)	GraphoLearn	English	L2	Phonics and phonological awareness and word reading	Tablet	Learners independent	8 weeks 20–30 min per session 6 sessions per week
Solheim et al. (2018)	On Track intervention with either additional Norwegian GraphoGame or On Track ABC application	Norwegian	L1	Phonics and word reading, text reading, spelling and reading comprehension	Tablet	Learners independent	25 weeks 4 sessions per week 45 min per session
Baker et al. (2017)	Spanish GraphoGame	Spanish	L1	Phonics, phonological awareness and word reading	Computer	Learners independent	16 weeks 3 sessions per week 10 min per session
Bennett et al. (2017)	Reading RACES	English	L1	Reading fluency and comprehension	Computer	Researcher	7–13 weeks 3–5 sessions per week 20–30 min per session
Horne (2017)	Comprehension Booster	English	L1	Reading and listening comprehension	Computer	Learners independent	6 weeks School 1: 1 session per week (30 min) School 2: 2 sessions per week 30 min per session
Kleinsz et al. (2017)	Chassymo LoCoText	French	L1	Decoding (using a grapho-syllabic approach) Reading comprehension	Computer	Learners independent	5 weeks 30 min per day; 4 days per week Total of 10 h
Madden and Slavin (2017)	Tutoring with Alphie	English	-	Phonics, phonemic awareness, word reading, fluency, vocabulary, and reading comprehension	Computer	Trained tutors	School year 5 sessions per week; 30 min per session
Mak et al. (2017)	ABRACADABRA	English	L2	Phonics, phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension and writing	Computer	Trained teachers	School year 3 sessions per week; 105 min per week
Moser et al. (2017)	Word identification through teaching word patterns (phonics) with auditory, visual and tactile modalities	English	L1	Placing word parts into correct sequence, phonics, word writing, phonological awareness, word reading and typing	iPad	Learners independent	10 weeks 5 sessions per week 10–15 min per session

TABLE 2-A1 continues on the next page →

TABLE 2-A1 (Continues...): Characteristics of the interventions included in the information and communication technology-based reading intervention literature review papers.

Study	Name or description	Language of intervention (L1) or second (L2) language	Language of intervention (L2) language	Skills targeted in activities	Mode of delivery	Facilitator	Dosage
Ozbek and Girli (2017)	Pre-listening, repeated reading, performance feedback and reward techniques	Turkish	L1	Reading fluency	iPad	Researcher	1 session per week 13–15 sessions 20 min per session
Van de Ven et al. (2017)	Letter Prince	Dutch	L1	Phonics, word reading, reading comprehension and fluency	iPod	Adult assistant	9 sessions 15 min per session
Abrami et al. (2016)	ABRACADABRA	English	L2	Phonics, phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension and writing	Computer	Trained teachers	13 weeks 2 h per week
El Zein et al. (2016)	Space Voyage	English	-	Reading comprehension	iPad	Trained research assistant	16 sessions 35 min per session
Lindeblad et al. (2016)	Computers Prizmo, Easy Writer, SayHi, Translate, Dragon Search, Voice Reader, Web, Ruzzle, Hang Man, Dasy Reader, and Vod	Swedish	L1	Passage reading, reading fluency and comprehension	Smartphones and tablets	Trained special education teachers	5 weeks 4 sessions per week 18 sessions (M) 40–60 min per session (47 min=M)
Schneider et al. (2016)	MindPlay Virtual Reading Coach	English	Mixed	Phonics, phonemic awareness, fluency, vocabulary, comprehension, print concepts, and grammar	Computer	Learners independent	School year 4 sessions per week 30 min per session
Must-Rao et al. (2015)	The Sight Words: Kids Learn App	English	L2	Sight word reading	iPad	Teacher (study 1) Learners independent (study 2)	Study 1: 13 weeks; 3 sessions per week; 17–33 sessions per child; 10 min per session. Study 2: 12 weeks; 21–30 sessions; 10 min per session
Shannon et al. (2015)	Accelerated Reader	English	L1	Learners choose reading materials and set goals; assessing comprehension by providing feedback to learners and teachers	Computers	Trained teachers	School year 24 weeks 4–5 times per week
Tyler et al. (2015)	Headsprout Early Reading	English	Mixed	Phonological awareness, print awareness, phonics, fluency	Computers	Learners independent	8 months 45 min sessions Five days per week Total of 80 sessions
Jere-Folotiya et al. (2014)	ciNyanja GraphoGame	ciNyanja	L1	Phonics and letter-sound knowledge	Cell phone	Learners independent	7–9 min sessions; 6 sessions per day; 3–5 days per week; 94 min (M) total intervention
Kamykowska et al. (2014)	Polish GraphoGame	Polish	L1	Phonics, word reading	Computer	Learners independent	15 min sessions
Larabee et al. (2014)	Build a Word – Easy Spelling with Phonics	English	Mixed	Phonics, word reading and pseudoword reading	iPad	Researcher	2 weeks 4 sessions per week 9 sessions 7.65 min per session (M)
Lysenko and Abrami (2014)	Combined ABRACADABRA and ePearl	English	L1	Phonics, word reading, reading and listening comprehension, reading fluency meta-cognition in reading and writing	Computer	Trained classroom teachers	1 school year 2 h per week
Rivera et al. (2014)	Vocabulary instruction during shared reading	English and Spanish	Both	Expressive vocabulary	iPad	Special education teacher	4 weeks
Walcott et al. (2014)	Earobics	English	L1	Phonics, phonological awareness and word reading	Computer	Researcher (2 days per week) and teacher (2 days per week)	Study 1: 4 weeks; 4 sessions per week; 20 min per session Study 2: 5 weeks; 4 sessions per week; 20 min per session
Cullen et al. (2013)	Kurzweil 3000	English	L1	Sight word reading	Computer	Learners independent	3–5 sessions per week 2–7 sessions in total 20–25 min sessions
Ecalle et al. (2013)	Chassymo Oppositions Phonologiques	French	L1	Word reading and phonological awareness (grapho-syllabic and phonemic word processing)	Computer	Learners independent	10 weeks; 4 sessions per week; 30 min per session (10 h of total intervention)
Fälth et al. (2013)	Omega-interactive sentences (comprehension training) COMputerized PHOnological Training (phonological training)	Swedish	L1	Word reading, sentence reading, vocabulary and reading comprehension Phonics and letter-sound knowledge, phonological awareness and word reading	Computer	Special education teacher	25 sessions 15–20 min per session (7 h 41 min of total intervention (M))

TABLE 2-A1 continues on the next page →

TABLE 2-A1 (Continues...): Characteristics of the interventions included in the information and communication technology-based reading intervention literature review papers.

Study	Name or description	Language of intervention	Language of intervention child's first (L1) or second (L2) language	Skills targeted in activities	Mode of delivery	Facilitator	Dosage
Heikkilä et al. (2013)	Finnish GraphoGame	Finnish	L1	Syllable reading speed, syllable recognition	Computer	Learners independent	2–3 weeks 3–5 sessions per week 5–10 min per session 10 sessions
Kyle et al. (2013)	English GraphoGame Phoneme	English	L1	Phonics, phonological awareness and word reading, focusing on phoneme level	Computer	Learners independent	12 weeks 5 sessions per week 10–15 min per session (11 h of total intervention (M))
Potocki et al. (2013)	English GraphoGame Rime	-	-	Phonics and letter-sound knowledge, phonological awareness and word reading, focusing on rime level	-	-	-
Ponce et al. (2012)	LoCoTex	French	L1	Reading comprehension	Computer	Learners independent	5 weeks; 4 sessions per week; 30 min per session; (10 h of total intervention)
	Spanish e-PELS	Spanish	-	Reading comprehension	Computer	Trained teachers	School semester 30 sessions 90 min per session
Chambers et al. (2011)	Team Alphie	English	-	Phonics, phonological awareness, sight words, word reading, spelling, visual tracking, fluency, and reading comprehension	Computer	Trained adults and peers within each group	School year 4–5 sessions per week 45 min per session
Gustafson et al. (2011)	Combined COMputerized PHOnological Training and Omega- Interactive Sentences	Swedish	L1	Phonics, phonological awareness and word reading, sentence reading, vocabulary and reading comprehension	Computer	Trained special education teachers	25 sessions; 10–25 min per session (total intervention: Phonological training 422.2 min (M); Comprehension training 443.5 min (M); Combined training 480.9 min (M); Ordinary special instruction 502.7 min (M))
Kim et al. (2011)	Read 180	English	-	Phonics, phonological awareness, word reading, fluency, vocabulary and reading comprehension	Computer	Trained teachers	23 weeks 4 sessions per week 60 min per session
Saine et al. (2011)	GraphoGame	Finnish	L1	Phonics, phonological awareness and word reading	Computer	Learners independent	28 weeks; 4 sessions per week; 45 min per session; (66 h of total intervention)
Yaw et al. (2011)	Sight words taught on computer screen	English	L1	Sight word reading	Computer	Researcher	16 sessions 2–4 sessions per week 3–33 min per session
Kim et al. (2010)	Read 180	English	-	Phonics, phonological awareness, word reading, fluency, vocabulary and reading comprehension	Computer	Trained teachers	23 weeks 4 sessions per week 60 min per session
Savage et al. (2010)	ABRACADABRA	English	L1	Phonics, phonemic awareness, word reading, fluency, vocabulary, listening and reading comprehension, spelling and writing	Computer	Trained teachers	8 weeks 2 h per week Total of 16 h of intervention
Torgesen et al. (2010)	Read, Write and Type (RWT) The Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech (LIPS)	English	L1	Phonics, phonological awareness, word and passage reading, spelling, writing and typing Phonics, phonological awareness (oral motor and articulation awareness approach), word and passage reading, spelling/writing	Computer	Trained teachers (half the time) and learners independent (half the time)	8 months 4 sessions per week 50 min per session (80 h of total intervention)
Ecaile et al. (2009)	A whole word recognition approach (control group) A syllabic unit word recognition approach (treatment group)	French	L1	Word reading Phonological awareness (syllable level) and word reading	Computer	Learners independent	5 weeks 2 sessions per day 15 min per session (10 h of total intervention)
Macaruso and Rodman (2009)	Lexia Strategies for Older Students	English	-	Phonics, phonological awareness, word reading, reading fluency and comprehension	Computer	Learners independent	50 sessions (M) 8 months 2–3 sessions per week 20–30 min per session
Savage et al. (2009)	ABRACADABRA	English	Mixed	Phonics and letter-sound knowledge, word reading, reading fluency, reading and listening comprehension, and writing	Computer	Trained facilitator	4 sessions per week 20 min per session

Note: Papers are ordered chronologically by year and alphabetically within years. Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.
M, mean; L1, first language; L2, second language.

TABLE 3-A1: Outcome measures and results of the studies included in the information and communication technology-based reading intervention literature review.

Study	Outcome measures	Results
Council et al. (2019)	Informal measures of reading fluency and comprehension.	Improved reading fluency and comprehension.
Lysenko et al. (2019)	Standardised measures of word reading, word meaning (vocabulary), reading comprehension, listening comprehension and national examination results in English and the following subjects taught in English: Social Studies, Mathematics and Science.	Phase I and II results showed a significant difference between experimental and control groups (in favour of the experimental group) on measures of word reading, vocabulary, reading comprehension and listening comprehension. Experimental participants significantly outperformed control participants in the subject examinations.
Mize et al. (2019)	Informal measures of word reading accuracy and fluency.	All children's reading accuracy and fluency increased (the number of correct words read per minute) as a result of the intervention.
O'Brien et al. (2019)	Standardised measures of reading and decoding accuracy, reading and decoding fluency, and spelling of words.	Phase 1: All groups improved significantly on all outcome measures. There was no difference among the performance of the three different intervention groups. Phase 2: All groups improved significantly on all outcome measures. There was no difference among the performance of the three different intervention groups except that decoding accuracy showed greater improvement for the phoneme-level intervention group compared to the rime-level intervention group.
Barber et al. (2018)	Informal measures of reading fluency and comprehension.	Children improved in reading fluency and comprehension as a result of the intervention.
Messer and Nash (2018)	Standardised measures of phonological awareness, phonological short-term memory, executive loaded working memory, naming speed, decoding and spelling.	The experimental group had significantly higher scores than the control group on measures of decoding, phonological awareness, naming speed, phonological short-term memory and executive loaded working memory.
Ngorosho (2018)	Informal lexical decision tasks for letters, syllables and words and informal single word spelling test. Informal measures of letter knowledge and word reading.	Significant improvement was found for both GraphoGame and classroom instruction interventions. GraphoGame intervention led to greater improvement than classroom instruction intervention.
Patel et al. (2018)	Informal GraphoLearn in-game assessments: grapheme-phoneme knowledge, rime unit recognition, whole word reading. Standardised measures of word reading, sight word reading efficiency, pseudoword reading efficiency and spelling.	Significant differences in favour of the intervention group for all GraphoLearn in-game measures. No significant differences between groups on standardised measures. Both groups showed improvement on all measures from pre-test to post-test.
Solheim et al. (2018)	Standardised measures of word reading, sentence reading and spelling.	Both treatment groups had statistically significantly higher word reading, sentence reading and spelling skills than the control group at post-test follow-up 1 and 2 years later.
Baker et al. (2017)	Standardised measures of Spanish pseudoword and word reading, standardised measures of English pseudoword reading and English reading accuracy and fluency.	No significant difference in the gains on Spanish pseudoword and real word reading accuracy and fluency between the intervention and control conditions. No significant difference in gains on English reading.
Bennett et al. (2017)	Non-standardised measures of reading fluency and comprehension.	Reading fluency and comprehension improved for practised and novel passages during intervention and on the 2 week and 1 month follow-ups.
Horne (2017)	Standardised test of reading comprehension, reading rate and reading accuracy.	Significant effects for reading comprehension and accuracy but not for rate. The intervention group in school 2 (two sessions per week) demonstrated significantly larger gains in reading accuracy and comprehension than the group in school 1 (one session per week).
Kleinsz et al. (2017)	Standardised assessments of word reading, decoding, phonological skills, decoding fluency, receptive vocabulary and non-verbal reasoning. Informal measures of listening comprehension, reading comprehension, comprehension monitoring, and working memory.	Grapho-syllabic training led to improved performance in written word recognition (as well as phonological awareness and decoding). Comprehension training improved listening and reading comprehension (and vocabulary and comprehension monitoring).
Madden and Slavin (2017)	Standardised assessments of word reading, fluency and comprehension.	Reading skills improved significantly in intervention group compared to control groups.
Mak et al. (2017)	Standardised measures of word reading, vocabulary reading, listening comprehension, phoneme segmentation fluency, and phoneme blending fluency.	Learners in the intervention scored significantly higher than control learners on vocabulary, reading, phoneme segmentation and blending fluency. Both groups performed similarly for word reading, and listening comprehension.
Moser et al. (2017)	Standardised measures of vocabulary, reading comprehension, rate, accuracy, and spelling.	No intervention effects were found; intervention and control participants showed no significant differences in any areas.
Ozbek and Girli (2017)	Informal measures of reading fluency.	Intervention improved the reading fluency of the learners.
Van de Ven et al. (2017)	Standardised tests of pseudoword reading, word and text reading, receptive vocabulary.	Intervention effects were found for pseudoword reading and reading fluency.
Abrami et al. (2016)	Norm-referenced tests of reading, reading vocabulary, reading comprehension, listening comprehension and end-of-year examination results in English and other subjects taught including Social Studies, Mathematics and Science.	Intervention group made significant gains in reading and listening comprehension compared to the control group. No significant difference between the groups on other measures. Intervention group outperformed children in the control group in the exams (small effect size).
El Zein et al. (2016)	Informal measure of reading comprehension.	Teacher-directed instruction was more effective than iPad instruction for increasing the accuracy of responses.
Lindeblad et al. (2016)	Standardised measures of word reading, sentence reading, non-word reading, reading comprehension.	Significant improvement in reading and reading comprehension between pre-test and post-test measures. At a 1-year follow-up, the children in the intervention group had developed reading skills at a rate equivalent to typically developing children.
Schneider et al. (2016)	Standardised measures of word reading, pseudoword reading, word spelling, pseudoword spelling, and word reading fluency.	Intervention group improved significantly more than children in the control group on measures of word spelling, non-word spelling, and word fluency. Significant effects were not detected for non-word and real word reading but there were non-significant differences favouring learners in the treatment group.
Musti-Rao et al. (2015)	Informal measures of sight word reading; standardised measures of reading fluency.	Improvements in sight word reading; gains not achieved for oral reading fluency.
Shannon et al. (2015)	A norm- and criterion-referenced assessment of word knowledge, analysing literary text, understanding author's craft, comprehension strategies and constructing meaning, and analysing argument and evaluating text.	The intervention group showed significantly greater gains on the assessment than the control group. A moderate effect size was found. The programme had a positive impact on learner's reading achievement.
Tyler et al. (2015)	Standardised measures of reading accuracy, fluency and word recognition.	Significant improvements in favour of the intervention group for reading accuracy but not for reading fluency or word recognition.
Jere-Folotiya et al. (2014)	Standardised tests of orthographic awareness and spelling.	Intervention improved the spelling of participants (intervention learners significantly outperformed control learners).
Kamykowska et al. (2014)	Standardised tests of phonics and letter-sound knowledge, word reading speed, pseudoword reading speed, non-verbal abilities, and receptive vocabulary.	No differences between the group who received GraphoGame intervention and a Maths intervention on study outcomes; no intervention effect.
Larabee et al. (2014)	Informal measures of phonics and letter-sound knowledge, words and pseudowords.	No difference between iPad instruction and instruction with typical materials on letter knowledge and word reading. Impact of iPad intervention on reading performance was mixed.

TABLE 3-A1 continues on the next page →

TABLE 3-A1 (Continues...): Outcome measures and results of the studies included in the information and communication technology-based reading intervention literature review.

Study	Outcome measures	Results
Lysenko and Abrami (2014)	Standardised measures of vocabulary, reading comprehension, listening comprehension and writing.	Intervention resulted in significant gains in vocabulary and reading comprehension but not listening comprehension or writing.
Rivera et al. (2014)	Informal measure of expressive vocabulary.	Expressive vocabulary for the target words improved in English and Spanish as a result of the shared story reading, which contained vocabulary instruction.
Walcott et al. (2014)	Standardised measures of reading fluency and phoneme segmentation and researcher-developed observational measures for attention-to-task.	For study 1 and 2, all participants had improvements in oral reading fluency, phoneme segmentation, and attention-to-task relative to their baseline functioning.
Cullen et al. (2013)	Informal measure of sight word reading.	Intervention resulted in participants acquiring all sight words and maintenance effects were present 4 weeks after intervention.
Ecalle et al. (2013)	Standardised assessment of word reading for study 1. Standardised assessment of silent word recognition, aloud word reading, and reading comprehension for study 2.	Study 1: children from the grapho-syllabic training group significantly outperformed children from the grapho-phonemic training and control group in word reading. Study 2: children in the grapho-syllabic and grapho-phonemic training groups both showed gains on silent word recognition, word reading and reading comprehension.
Fälth et al. (2013)	Standardised measures of sight word reading, word reading, pseudoword reading, phonological awareness (deletion) and reading comprehension.	Statistically significant improvements were made for all groups on all measures. Typically developing readers made the greatest improvements followed by (in order from highest to lowest gains) the combined treatment group, the word phonological group, the comprehension group, and the regular special instruction group.
Heikkilä et al. (2013)	Non-standardised measures of syllable reading, pseudoword reading, passage reading and rapid automatized naming.	Intervention children read trained syllables significantly faster than the control group. There were no significant differences between the groups' reading speed for untrained syllables; there were no differences between the groups on passage reading speed.
Kyle et al. (2013)	Standardised measures of reading, spelling, and phonological awareness.	Both games lead to improvements in reading, spelling and phonological awareness; gains were maintained at a 4-month follow-up.
Potocki et al. (2013)	Non-standardised measures of listening comprehension, reading comprehension and comprehension monitoring; standardised measure of receptive vocabulary.	The experimental group progressed more between the pre-test and the two post-tests sessions and the difference between the groups was significant at the second post-test (11 months after the training phase). For vocabulary and comprehension monitoring, a significant difference between the experimental group and the control group was only present at the first post-test.
Ponce et al. (2012)	Standardised measure of reading comprehension.	The intervention group performed significantly better than the control group on reading comprehension.
Chambers et al. (2011)	Standardised measures of letter knowledge, word reading, pseudoword reading, and reading comprehension.	For Grade 1, the intervention group outperformed the control group on all three reading measures. For Grade 2, there was no significant difference between the intervention and control groups.
Gustafson et al. (2011)	Standardised measures of sight word reading, word decoding, pseudoword reading, reading comprehension and passage comprehension.	The three intervention groups improved their reading skills at least as much as the comparison groups.
Kim et al. (2011)	Standardised measures of reading comprehension, spelling, vocabulary, reading accuracy and reading rate.	A significant difference between the intervention and control groups on measures of vocabulary and reading comprehension.
Saine et al. (2011)	Standardised measures of letter knowledge, reading accuracy, fluency and spelling.	Children in the computer-based intervention group improved during Grade 1 and continued to progress similarly in the follow-ups conducted 12 months and 16 months after the intervention had ended. The overall gains in the computer-assisted intervention were significant for letter knowledge, decoding, accuracy, fluency and spelling.
Yaw et al. (2011)	Informal measures: Dolch sight word lists.	Intervention improved sight word reading significantly compared to multiple baseline measures.
Kim et al. (2010)	Standardised measures of sight word reading, vocabulary, reading comprehension, phonetic decoding, reading accuracy and reading rate.	No significant difference between the reading performance of the intervention and control groups on post-test measures of sight word reading, phonetic decoding, vocabulary and comprehension. Children in the intervention group performed significantly higher on measures of reading fluency (accuracy and rate) but this phenomenon was only found for children in Grade 4.
Savage et al. (2010)	Informal measure of grapheme-phoneme knowledge. Standardised measures of listening comprehension, word reading, word meaning, vocabulary, sentence comprehension, passage comprehension, spelling, pseudoword reading, phonological awareness, and arithmetic.	There were significant differences in students' reading outcomes across the intervention groups.
Torgesen et al. (2010)	Standardised measures of word accuracy and fluency, phonemic decoding accuracy and fluency, text reading accuracy and fluency, reading comprehension, phonological awareness, rapid naming, and spelling.	Reading outcomes were slightly stronger in the group that received the Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech intervention compared to the group that received the read-write-type intervention, but this finding was not statistically significant.
Ecalle et al. (2009)	Non-standardised tests of word recognition, reading words aloud, and word spelling.	The treatment group significantly outperformed the control group at all three post-tests on measures of word recognition, reading words aloud and word spelling. Large treatment effects were observed.
Macaruso and Rodman (2009)	Standardised measures of single word reading, pseudoword reading, reading fluency, reading vocabulary, reading comprehension, listening comprehension, and spelling.	Intervention learners showed significantly larger gains than control learners on measures of decoding skills. Intervention learners showed a trend towards greater gains than control learners on word reading. Both groups had improved reading comprehension.
Savage et al. (2009)	Standardised measures of letter-sound knowledge, listening comprehension, word reading, word meaning, sentence comprehension, passage comprehension, reading fluency, pseudoword reading, and phonological awareness (deletion, blending).	For the analytic phonics programme, there were significant improvements in letter knowledge. For the synthetic phonics programme, there were significant improvements in phonological awareness, listening comprehension, reading comprehension, and reading fluency. Both interventions had a significant impact on literacy at post-test and follow-up.

Note: Papers are ordered chronologically by year and alphabetically within years. Please see the full reference list of this article, Dean, J., Pascoe, M. & Le Roux, J., 2021, 'Information and communication technology reading interventions: A scoping review', *Reading & Writing* 12(1), a294. <https://doi.org/10.4102/rw.v12i1.294>, for more information.