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Benefits of using ICT in school activities by students with motor, speech, visual and hearing impairment: A literature review

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Abstract

Introduction: Information and communication technology (ICT) has the potential to enhance participation in educational activities for students with physical disabilities. Even though incorporating ICTs into teaching and learning in education has become an important issue, it is unclear what evidence research has provided. Aim: To investigate type of ICT items and how ICT is being used by students with physical disabilities, and describe benefits of ICT use in school activities. Method: A systematic literature search, covering the period 2000-May 2012, was performed in the databases AMED, CINAHL, Eric, OTseeker, Psych Info, PubMed, and Scopus. Data analysis entailed extracting, editing, grouping, and abstracting findings. Results: A total of 32 articles were included, 16 of which were intervention studies. More than half of the studies concerned students with motor impairments. Type of ICT used differed among impairment groups, and ICT seemed to be especially beneficial for writing, spelling and communication. Conclusion: Even though the review found heterogeneity across the studies students seemed to benefit from ICT use regardless of the type. For future research it is important to highlight intervention studies especially for students with visual, hearing and communication impairments.

Introduction

The rationale for using information and communication technology (ICT), technologies for the manipulation and communication of information through voice and sound, or images such as computers, computer-based assistive technology, special software, communication aids, in schools by students with physical disabilities is to prepare all students for participation in the information society (1, 2). Incorporating ICTs, particularly computers and the Internet, into teaching and learning in education to increase the students "digital skills" has therefore become an important issue in both economically developed and rapidly developing countries (3-7). Consequently, from an equality perspective, all students should have equal opportunity and appropriate support to acquire competence with the technology, irrespective of whether they have a physical disability or not (8, 9). However, for students with disabilities, the literature appears to support the use of ICT as an assistive technology device (ATD), specifically designed to assist and enable an individual's participation, to a varying degree, in all occupational performance areas, but particularly in education, communication and play (10-12).

Despite ICTs have been available in schools in many western countries in some decades, much of the research on using ICT in education has focused on benefits by children without disabilities (1, 3, 4, 13). Empirical research is spare in regard to how ICT enhances the participation of children with physical disabilities in school activities (14, 15). However, the literature has emphasised that ICT, as a computer-based ATD has the *potential* to enable children with physical disabilities to participate more fully in everyday activities, e.g. access to the class curriculum (14, 16-18). The World Health Organization (WHO) for example stresses that ATDs are one strategy that can be used by children with disabilities to improve functioning and minimize the impact of environmental barriers to their participation in everyday life, such

as school activities (19). Therefore, research into the benefits of ICT use for participation in school activities for these students is needed (20, 21).

Regarding children and youths with physical disabilities i.e. children with motor impairment (e.g. cerebral palsy, acquired brain injury), speech (communication), visual (blind, low vision) and hearing impairment (deaf, hearing loss), several studies have shown that their participation in school activities is restricted when compared with children without disabilities (18, 22-24). In International Classification of Functioning, Disability and Health- children and youth version (ICF-CY) participation is consistent with "an individual's involvement in a life situation" (19). Participation is also an essential aspect of children's health and well-being. Through participation in school children acquire academic knowledge, but also learn about the expectations of society, learn to communicate and get along with others and develop the skills and competencies they need to become successful in their communities, thus gain increased opportunities to work in adult life (19, 25). Although the literature suggests that ICT has the potential to enhance participation for children with disabilities in everyday activities (14, 26-30), it is unclear what evidence research has provided whether ICT enhances participation in educational activities (31). In addition, scholars (2) argue that studies on the quality of technology use are lacking in this research area, i.e. *how* technology is used, *why* and *the benefit* of use. A literature review will find out if empirical studies into the benefits of ICT use in school activities for students with physical disabilities are still needed. Therefore, the aim of the review is to investigate, type of ICT items and how ICT is being used by students with physical disabilities, and describe benefits of ICT use in school activities.

Method

Inclusion and exclusion criteria

This literature review followed a systematic and structured methodological approach (32-34). The authors started by constructing a list of inclusion criteria that were intended to guide the

search for articles. Inclusion criteria for the first database search were: a) only primary research, b) both qualitative and quantitative studies, c) articles published in English-language peer-reviewed journals, d) articles published in this century (from January 2000 to May 2012), on the basis of the rapid technical development, e) a study population of students with physical disabilities between 6- 19 years of age, e) intervention studies with some type of ICT and f) benefits measured needed to address the use of ICT in school activities.

Initially, the intention was to include only intervention articles where the focus was on the outcome of ICT use in school activities. When the articles were read in full text, it appeared that many of the studies consisted of cross-sectional and descriptive designs, and the test environments were also often rehabilitation centres and clinics. Therefore, the inclusion criteria were revised to also include: descriptive studies. The use of ICT in "school activities" were accepted to be performed in environments other than schools, for example the rehabilitation clinic if the ICT were intended to be used in school.

Thus, studies that focused solely on outcomes relating to the ICT product design were excluded.

Search strategy

To locate and identify relevant articles a range of electronic databases (AMED, CINAHL, Eric, OTseeker, Psych Info, PubMed, Scopus) and reference and related citation lists in included articles were used (32). Beyond this, the journals *Assistive Technology, Technology and Disability,* and *Disability and Rehabilitation: Assistive and Technology* (available from 2006 volume: 1) were manually searched for the period 2000 to May 2012.

Following Schlosser, Koul and Costello (35) the template PICO (patient, intervention, comparison and outcome) was used for asking of a well-constructed question and finding words for searching. The searches undertaken used combinations of the Patient: *physical*

disabilities OR *disabled children OR hearing impairment OR visual impairment OR speech impairment* AND some of following search words for the Intervention: *ICT* OR *information communication technology* OR *computer* OR *computer-based assistive technology AND assistive technology* OR *self-help devices* and the Outcome: *education* OR *school work* OR *educational activities OR participation* OR *engagement*. Comparison, i.e. the C in PICO was not topically in present review.

Search outcome

The database search resulted in 603 relevant titles which were screened by the first author, resulting in 325 identified abstracts. A manual search in the above-mentioned assistive technology journals resulted in another 3 abstracts. Duplicates and abstracts that clearly did not fulfil the inclusion criteria were excluded (n=212). Therefore, 116 abstracts were retrieved in full-article form to judge all the inclusion criteria. Of these, 82 articles were rejected, e.g. because of the study population was students without physical disabilities, or the participants were adults. The first author read each of the 34 articles, and scanned the reference lists of these articles. Additional articles were found when the reference lists in the included articles were scanned (n=7). The number of articles included into this step comprised 41 full-text articles. Figure I describes the selection process.

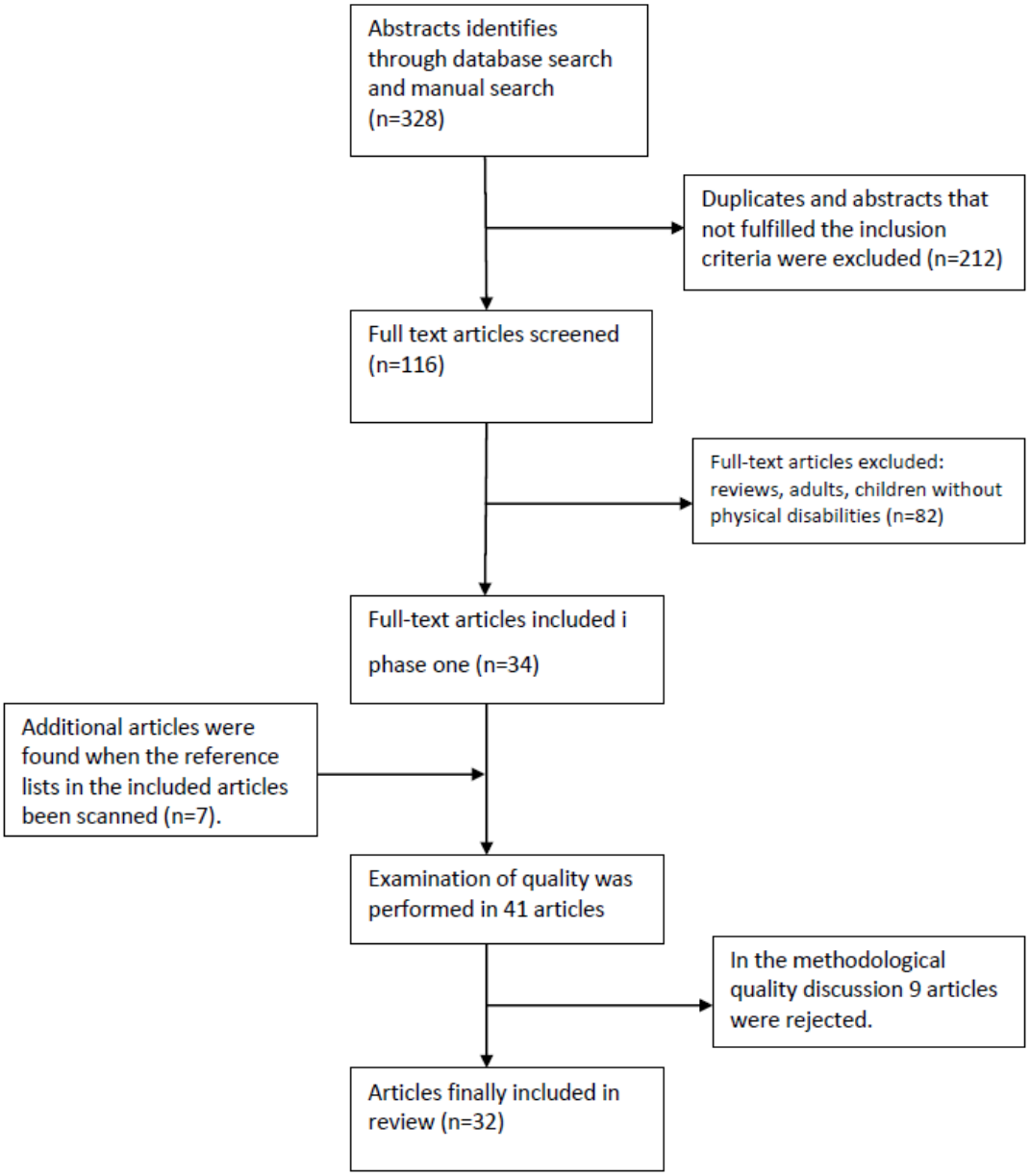

Figure I Flow-chart showing the process of identifying and selecting the included articles.

Data extraction and analysis

The Research Pyramid (36) has given the arguments for inclusion of both qualitative and quantitative research in this literature review. The critical review forms for quantitative and qualitative studies developed by the Occupational Therapy Evidence-Based Practice Group at McMaster University, Canada (37-39) were used to evaluate internal validity. These forms allow the reviewer to summarize information and evaluate the quality of the studies' purpose, background literature, design of the study, sample size, outcome measures, interventions and results. When the methodological quality was discussed by the authors, nine articles were rejected from the 41 full-text articles.

To compare and contrast the results of each study, data were extracted and organized in a matrix (32). In the first phase the matrix was used to classify each article into categories, according to the type of research used: author/s/, year, country of origin, design, sample and measurement, purpose of the study, purpose of ICT use, as well as reported outcome of ICT use. In the next phase in the analysis process the completed matrix was used to group the studies reviewed in terms of students with mild and severe motor impairment, speech, visual and hearing impairment. In the third phase, type of ICT was identified and classified in relation to the type of impairment group. Four ICT categories emerged: 1) text-generating hard- and software (e.g. computer, word processing, word prediction software), 2) speech-generating hard- and software (e.g. communication aids, text-to-speech device, speech synthesizer), 3) access solutions (e.g. computer input interface, screen-keyboard), and 4) special software (e.g. software for education in maths, spelling, multimedia software). In the last phase the benefits of ICT use in each ICT category were analysed with the help of the matrix and the analysis in phase three, that is, ICT type in relation to type of impairment group.

Results

A total of 32 studies met the inclusion criteria for this review, presented in Tables II-VI. The countries of origin for the studies reveal that about one third of the 32 studies were conducted in the U.S.A. (*n* = 12), the remainder were conducted in Canada (*n* = 5), Australia (n=4), Sweden (n=3), Italy and Brazil (*n* = 2), and one in Finland, Israel, the Netherlands, and Spain, respectively. No studies were found from Asian and African countries.

Methodological aspects

In the present review, most of the studies (n=26) have a quantitative design: two with cohort designs (40, 41), single-subject design (*n* = 4)(42-45), before-after design (n=10) (46-55) , case-study design (descriptive) (*n* = 5) (56-60), and six studies with a cross-sectional design (*n* = 6) (61-66). Five studies have a qualitative design (67-71).

Table I presents the sample sizes in the four studied groups of students, that is, students with motor, speech, visual and hearing impairment. Altogether, two third of the studies reported a range of participants numbers from one to 15. In the group of students with speech impairment, all five studies had fewer than sixteen participants. All studies with students with hearing loss had between 6 and 30 participants.

Table I. Student groups in relation to sample sizes of participants (students, or their parents, teachers, therapists) in the studies.

	Sample sizes			
Student group	1-5	6-15	16-30	Over 30
Students with motor impairments (n=17)	7	3	5	2
Students with speech impairments (n=5)	2	3		
Students with visual impairments (n=5)	1	2		2
Students with hearing loss (n=5)		2	3	
Number of Studies	10	10	8	4

In the review, more than half of the studies (17/32) concerned students with motor impairments use of ICT seven studies of these involved students with handwriting difficulties (42-44, 46-48, 66) (Table II) and 10 with students profound motor impairment (45, 49, 50, 57, 61-64, 67, 71) (Table III). The remaining 15 studies were divided equally into students with speech impairment (51-53, 68, 69) (Table IV), students with visual impairment (56, 58, 59, 65, 70) (Table V) and finally, students with hearing impairment (40, 41, 54, 55, 60) (Table VI).

Half of the studies (16/32) (40-55) were intervention studies, where academic skills were addressed in nine studies (40-44, 46, 47, 51, 53, 55), and skill improvement in the use of the computer was targeted in six of the included studies (45, 48-50, 52, 54). The focuses of five studies were product development (56-60). In these studies new types of devices and software, e.g. talking tactile tablet, multi-camera tongue switch, software in a virtual reality immersive environment, were tested in different school activities, e.g. learning math or writing. The remaining eleven descriptive studies delineated the use and non-use of ICT (e.g. access, satisfaction, as well as which activities) in school activities (61-70).

Type of ICT items and how ICT is used for students with physical disabilities

Students with mild to severe motor impairments

Six (42-44, 46-48) out of seven studies in students with mild motor impairment with handwriting difficulties (Table II) described and evaluated the use of a combination of text-generating hard- and software; computers and software, such as word processing, word prediction and or word-cueing programs. Use of computers and word-processing programs with and without word-prediction software has been studied by examining legibility (42, 44, 46, 47), speed in writing (42-44, 46-48), amount of written text (42-44, 47) but also the number of correctly spelled words (42, 44, 46-48) before and after the treatment period.

Table II. Studies included show use of ICT in students with mild motor impairment and handwriting difficulties

Source/Country	Handley-More et al. (2003)/ U.S.A. (42)	Hetzroni et al. (2004)/ Israel (43)	Klein et al. (2008)/ U.S.A. (44)	Miranda and Turoldo (2006)/Canada (46)
Purpose of the study	To investigate whether word processing and word prediction were effective in improving the written communication skills of children with learning disabilities and handwriting problems.	To investigate the use of a word processor for enhancing the academic outcomes of students with writing disabilities in a lower-secondary school.	To explore the potential of children with DCD to learn computer use, keyboarding and basic word-processing skills, and to compare the speed of their keyboarding with printing/handwriting.	To examine the impact of a word-prediction software program, on the written output of students with physical disabilities that affected their ability to write by hand.
Sample/Age	N=3, in grades 4 and 5.	N=3, 12 to 13 years old.	N=6, age 7 to 10.	N=24, age 8 to 19.
Type and purpose of ICT use	Computer, word-processing and word-prediction software. To produce more legible written work, faster and with decreased spelling errors.	Computer, word-processing software. To increase the written outcome and for enhancing individual productivity.	Computer, computer-skills program. To produce more legible written work, faster and with decreased spelling errors.	Computer, word-processing, word-prediction software. To produce more legible written work, faster, increase total amount and with decreased spelling errors.
How ICT was measured	A single-subject alternating treatments design was replicated. Percentages of legible words and correctly spelled words, total amount written, and rate of writing were assessed. Alternating among handwriting, word processing, and word processing with word prediction.	Intervention in an ABAB design with a training phase between phases A1 and B1. Pre-and post-test assessed per cent of spelling and reading errors, total numbers of words were assessed and structure and organization of the text.	Intervention in an ABAB design, with five replications. The computer skills program consisted of 10 one-hour sessions. Pre-and post-test were done in a printing/ handwriting task, with a computer skills checklist and in an observation sheet.	Intervention with word-processing and word-prediction software. A student survey and three writing samples where each student write for 10 minutes using handwriting and computer with word-processing software only, and a computer with both word-processing and word-prediction software.
Reported benefit of ICT use	Results were variable. Two children had significantly improvements in legibility (either word processing alone or with word prediction) and in spelling (word prediction). Though rate of writing was best for two children when using handwriting, relative to total amount produced; one method was not clearly preferable to another.	In paper-and-pencil phases, students produced outcomes that had more spelling mistakes, more reading errors, and lower overall quality of organization and structure in comparison with use of computer and a word processor. The results did not indicate any noticeable difference in the number of words per text.	All children showed improved word processing skills. Touch keyboarding speed increased for the five children but only one child acquired a speed comparable to printing/handwriting. Four children demonstrated increased text production when generating a story, but none achieved speeds comparable to printing/ handwriting. Therapists observed improved legibility and increased motivation.	Both word processing and word prediction positively affected legibility, but only word prediction positively affected spelling accuracy in comparison to handwriting. Co:Writer also had a positive impact on writing quality in comparison with both handwriting and word processing, as measured by the percentage and mean length of consecutive correct word sequences.

All studies in students with severe motor impairment included uses of computer and an access solution (Table III). These access solutions ranged from newly developed products, e.g. voice-detecting sensor (49), micro switch and keyboard emulator (45) and contact tongue protrusion

(57), as well as commercial products, such as switches and screen keyboards (50). The computer and the different access solutions were studied to facilitate students writing (45, 49), to interact with their surroundings (57), and to contribute to attaining students´ Individual Education Programme (IEP) goals (50).

Table III. Studies included show use of ICT in students with profound motor impairment

Source/Country	Brodin (2010)/ Sweden (61)	Hemmingsson et al. (2009)/ Sweden (71)	Lancioni et al. (2009)/ Italy (49)	Lancioni et al. (2011)/ Italy (45)	Leung & Chau (2010)/ Canada (57)
Purpose of the study	To ascertain whether ICT is used in schools to support inclusion and equal opportunities for children with motor disabilities. How do parents evaluate the use of computers at school? How are the communicative aspects of ICT used in the classroom?	The use and non-use of assistive technology devices in school by students with physical disabilities was investigated, and the students' experiences in using these devices are described.	To compared the effects of the voice-detecting sensor with those of a familiar pressure sensor.	To assess the effectiveness of micro switches for simple responses and a keyboard emulator to facilitate the writing performance of three participants with extensive motor disabilities.	To investigate a video-based access technology that facilitated a non-contact tongue protrusion access modality for a 7-year-old boy with severe spastic quadriplegic cerebral palsy.
Sample/Age	N=16 families, and a 15-year-old boy.	N=20, 8 to 19 years, and their occupational therapists.	N=2, 12.7 and 10.4 years old.	N= 3, 13, 45 and 46 years old	N=1, 7-years.
Type and purpose of ICT use	Computer, Internet, computer-based ATD, educational programs. For communication and inclusion to contribute equal opportunities in and outside school.	Computer, computer-based ATD, communication aid. To participate in school activities.	Computer, a voice-detecting sensor, a scanning keyboard emulator. To write and for communication.	Computer, micro switch and keyboard emulator. To provide opportunities to write with a computer.	Computer, tongue-switch. Interact with their surrounding world.
How ICT was measured	Descriptive from the parents' perspective for the most part. A parental questionnaire and an interview with one pupil.	Descriptive after intervention with an ATD from students' perspective. Semi-structured interview.	Intervention with an access solution. The performance with two type of access solutions, and a social validation check of their performance.	Intervention in an ABAB design. The time required for writing the words provided, the participants' answers to the preference checks before and after the intervention.	A descriptive case study in product development. Testing the access solutions in a computer game with matching.
Reported benefit of ICT use	Seven of fourteen parents describe that the computer improved communication (Internet, chat friends on the Web) and interaction with others. Fourteen of the parents reported difficulties with computer use at school and stressed that the competence was low among the teachers.	The main characteristics of ATDs that students with disabilities appreciated and wanted to use in school were the ATD's integration into teaching and learning and the students' experience of the ATD as enabling functioning in everyday school activities without threatening or complicating their social participation with peers.	The difference before and after in the boys' overall mean writing time per letter across sensors was, about 1.5 s. This difference favoured the pressure sensor for one of the boys and the voice-detecting sensor for the other boy. Both boys showed preference for the voice-detecting sensor.	The participated child had a faster writing performance during the B phases. The micro switch was considered relatively easy and convenient to manage and did not seem to cause any specific signs of tiredness.	Non-contact tongue protrusion modality via multiple camera video-based techniques can be a viable paediatric access pathway within a controlled environment for children with severe motor impairment.

Students with speech impairment

Table IV shows speech-generating hard- and special software studied in five studies, used in students with speech impairment. The three intervention studies focused on increasing the students' communication skills (51, 53) and spelling performance (52). Because students with speech impairment often had severe motor impairment, an access solution was needed as an input tool for the computer-based communication aids (53, 68), which often consisted of a screen keyboard which in turn controls a variety of software applications. These access solutions were not investigated in these included studies.

Table IV. Studies included show use of ICT in students with speech impairment

Source/ Country	Carpe, et al. (2010)/ Canada (68)	Kent-Walsh et al. (2003)/ U.S.A. (69)	Myers (2007)/U.S.A (51)	Rag Aus
Purpose of the study	To explore the perceptions of children with physical disabilities regarding their writing and communication aids.	To investigate the experiences of general education teachers who had included students with AAC in their classes.	To enhance the language and literacy skills of the participants to increase their participation in school activities.	To i thre spe spe
Sample/Age	N=10, age 8- 18 years, 1 parent and 2 OTs.	N= 11 education teachers of students with AAC aged 6-17 years.	N=4, age 5 -9	N=1
Type and purpose of ICT use	Text- and Speech-generating hard- and software, access solutions. Portable writing and communication aids enabling written productivity and literacy, and enabling community and school participation.	Speech-generating hard- and software (communication aids). To increase students' speech and the interaction with their typically classmates in classroom activities. To increase educational gains.	Speech-generating hardware and communication aids, computer/ communication software. To progress communication competence and increase participation and independence.	Spe in le
How ICT was measured	Children: in-depth interview. Parent and OTs: focus group.	Semi-structured interview with teachers.	An intervention programme with AAC in 4 weeks. Follow-up in school.	Thr met asse pre pha
Reported benefit of ICT use	Findings indicate that portable writing and communication aids are more than a means to enable written productivity and literacy. They also may help enable community and school participation, building of social relationships, and positive feelings of self.	The target students' speech and skill in operating their AAC systems improved when interacting with their typical classmates in classroom activities. Despite this, the students have been observed being excluded by their peers outside of the classroom. Whether use of AAC made educational gains or not was not assessed.	All students made progress in communication competence during the intervention period. Increased participation and independence were demonstrated for two participants in the follow-up in school. Computers and communication software were more familiar to school than complex dedicated devices.	The cor SPE und pos dev mo resu lear

Students with visual impairments

In Table V shows five studies in students with visual impairment and their use of ICT. Four of these had studied the students' use of speech-generating hardware together with special software applications (56, 58, 65, 70). In two studies new ICT items were tested with the purpose of making graphical elements in maths accessible (56, 58). In addition, an access solution system (single-switch text-entry system) was investigated to enable a student with visual impairment and severe motor impairment to use the computer for writing (59). The special maths software (56), the Talking Tactile Tablet (58) and an advanced text-entry solution

(59) were newly available devices and the students' performances were measured with and without the new products.

Table V. Studies included show in use of ICT in students with visual impairment

Source/Country	Beal et al. (2011)/ U.S.A. (56)	De Freitas Alves et al. (2009)/ Brazil (65)	Kelly (2009)/ U.S.A. (70)	Landau et al., (2003) /U.S.A (58)	Leung et al. (2010)/ Canada (59)
Purpose of the study	To field test a Self-voicing Computer Program for Pre-algebra Maths Problems.	To verify the application of ICT in the education of blind and low-vision students from the perceptions of their teachers.	To investigate the extent to which students who are visually impaired use ATD, the change in the use of ATD as time progressed, and several predictor variables that may have played a role in the use of ATD.	To investigate if use of the Talking Tactile Tablet (TTT) had a positive impact on the performance of students who were visually impaired and/or had difficulty visualizing graphics and diagrams.	The study investigated the text entry performance and learnability of the proposed system.
Sample/Age	N=14, in grades 5-12.	N= 134 education teachers, 58 of these teach students with visual impairment.	N= 297, aged 6-16 years.	N=8, .	N=1, 11-year.
Type and purpose of ICT use	Computer, special software. To increase the maths skills of youths with visual impairments.	Computer, computer-based ATD, software. To promote the inclusion of students with visual impairment, facilitating school tasks and social interaction.	Text-to-speech devices and computer screen-enlargement software. Make access to academic materials e.g. maths.	Talking Tactile Tablet (TTT). To make graphical elements from multiple-choice maths tests more accessible.	Computer, single-switch, special software, screen keyboard. To improve writing
How ICT was measured	Product development. Students' performance was assessed by percentage of correct answers and the number of incorrect answer attempts on each problem.	Descriptive from teachers perspective. Survey	Descriptive from parents', teachers', collaborators' perspectives. Structured interview in three waves of 4 years	Product development with experimental design. Two test forms were administered both in the standard accommodation and on the TTT. The third form was administered only on the TTT.	A descriptive case study with product development. Testing the character stroke disambiguation system in a word processor
Reported benefits of ICT use	The students' performance was significantly better on the easy problems than on the medium-difficulty problems and was the poorest on the hard problems in maths.	The participating teachers believed that using ICT in schools can promote the inclusion of students with visual impairment, facilitating school tasks and social interaction in the school environment.	Fewer than half of the students had the opportunity to use ATD during each of the three measured periods. The change in the use of ATD over time was not statistically significant. If parents were involved or the students attended residential schools were they significantly more likely to use ATD.	The results indicate that the TTT holds promise as a test-accommodation tool for visually impaired students.	The character stroke disambiguation system provided a functional text entry solution for the case study participant.

Students with hearing impairment

Students with hearing impairment using computers with special multimedia software applications were found in five articles, as can be seen in Table VI. Purposes of the use of special software in teaching were to facilitate learning of mathematics (60), to increase vocabulary for communication (54, 55), and reading (40).

Table VI. Studies included show use if of ICT in students with hearing impairment

Source/ Country	Adamo-Villani et al. (2010)/ U.S.A. (60)	Massaro et al. (2004)/ U.S.A. (54)	Perin da Silva (2012)/ Brazil (41)	Reitsma (2009)/ Netherlands (55)	Trezek et al., (2003)/ U.S.A. (40)
Purpose of the study	To describe the development steps of two novel approaches to teaching maths and science to deaf children using 3D animated interactive software	To test the effectiveness of a computer-animated tutor, for teaching new vocabulary items to children with a hearing loss.	To verify the applicability of a software in the (re)habilitation of hearing-impaired children.	To explore the effects of two different computer-based exercises for learning the associations between printed words and meanings.	To investigate whether the Corrective Reading-Decoding A curriculum could be modified to meet the needs of deaf and hard-of-hearing learners and result in enhancing the students' ability to demonstrate acquisition and generalization of phonic skills.
Sample/Age	N= 16, age 6-11	N= 8, 9-10 years	N= 17, age 6-12	N= 11, average age 7.10 years	N= 23, aged 11-15 years
Type and purpose of ICT use	3D animated interactive software. To increase the maths skills and science concepts in deaf children.	Computer, special software. To provide opportunities for better communication by increasing vocabulary.	Computer, special game software SARDA. The SARDA can be used by teachers to eliminate learning and language difficulties, in order to improve the children's quality of life.	Laptop and multimedia program. To read, spell and for communication with hearing people.	Computer, special software. To read and for communication with hearing people.
How ICT was measured	Product development. The evaluation of SMILE includes three forms: expert panel-based, formative and summative to measure the interface appeal.	Intervention: learn new vocabulary items in special software, 2 days a week for about 10 weeks. Follow-up after 4 weeks. Assessment tests on a set of words continued before and after training was completed.	Intervention with a multimedia program with exercises. The speech perception ability in quiet and in noise was assessed through the Hearing in Noise Test, before and after the auditory training.	Intervention with a multimedia program with exercises. Pre- and post-test was used to assess reading and signing skills.	Intervention with a phonic treatment package. Pre- and post-test and generalization test was used to assess reading skills.
Reported benefit of ICT use	For interface comparisons, there were no subject effects, but an animated interface resulted in reduced time task completion compared to static interfaces with and without sound and highlighting. These findings identify numerous features that affect software design.	The computer-animated tutor has been successful in teaching new vocabulary items to children with hearing loss.	The auditory training using the SARDA was effective, providing improvement of the speech perception ability, both in quiet and in noise, for both cochlear implant ~~CI~~ and hearing aid ~~HA~~ users.	After the training period, on average, half of the words were read correctly, whereas one fourth of the words were spelled correctly. It is very well possible for deaf children to learn new printed words by using computer-based exercises.	The treatment group had a higher mean score on phonic post-test compared to students in the comparison group. The treatment group also had a higher mean score on the generalization test compared to students in the comparison group.

Altogether the analyses indicate that the type of ICT used differed among impairment groups. The results in Table II and III show that text-generating hard- and software was the ICT which was most frequently studied in relation to students with mild motor impairment. Text-generating hardware was also studied, with a focus on access solutions or as a communication aid in the group of students with severe motor impairment with and without speech impairment. Computer-based communication aids where a type of speech-generating hardware and special software were, for obvious reasons, used for students with difficulties in speaking and communicating (Table IV). Table V shows that ICT, as speech-generating hardware together with special software applications, also occurred in four out of five studies in students with visual impairment. The auditive feedback may be a facilitator in reading and writing, as an option instead of reading and writing with the use of Braille (65). Finally, computers with special multimedia software applications were the types of ICT that had been used and studied in all articles in students with hearing impairment. Regarding how ICT was being used in the 16 intervention studies, Tables II-VI indicated that the purposes of the ICT interventions were

either to compensate for the disability (42-51, 53) or to exercise to improve functional capacity (40, 41, 52, 54, 55).

Benefits of ICT use in school activities

The outcomes in studies of students with mild motor impairment with handwriting difficulties (Table II) indicated that computer use with this type of ICT facilitated students' quality in writing (42-44, 46-48), such as decreased spelling errors and increased legibility. However, the students' writing speed had not increased in two (43, 44) out of six studies. In a survey, teachers held the opinions that laptop computers increased quality, speed and ease of written output, which improved self-confidence in students with mild motor impairment and also enabled equity with peers (66). Findings in three studies (42, 43, 66) indicated that conditions in the environment were crucial in terms of whether the outcome of ICT use was successful or not. Examples of beneficial conditions were access to computers and software (portable computers was preferable) and teachers' knowledge of the use of word-prediction programs. Other benefits reported, based on teacher and therapists observation, were children's increased motivation for writing and the fact that writing became less tiring when a computer was used (44, 47, 48).

In one study (50), the outcomes for students with severe motor impairment (Table III) and their use of access solutions were that ATDs as an intervention strategy were more successful than nine other possible intervention strategies to reach the students' IEP goals in special education. In the intervention studies (45, 49, 50), one indicated that the writing speed increased in one of two boys (49), another that one student's writing performance had increased through the use of a micro switch (45). Moreover, findings in a survey of students with motor impairment (62) showed that the computer improved opportunities as an educational tool (e.g.

to search for information), an alternative tool for learning (e.g. to exercise with special software) or as a compensatory tool in school activities (e.g. writing and communicating).

Findings showed positive outcomes relating to educational inclusion in students with speech impairment (51-53, 68, 69) (Table IV). The students' communications skills (51-53), such as answering and asking questions in class, increased, which facilitated participation in social activities in school and outside school. In one study (68), the students described that they used ICT as communication aids but also as a text-generating device for writing and reading. The AAC system provided also opportunities for independent play (53). Negative descriptions of using communication aid in classes were found, emerging from the students who used the devices, e.g. insufficient vocabularies, lack of related services, as well as poor usability (52, 69).

The outcome in studies related to visual impairment indicated (Table V) that all new products holds promise (56, 58, 59), e.g. provided a functional text-entry solution for students with low vision (59), even if the students had comments on the design of the products. The two (56, 58) intervention studies with the purpose of increasing the maths skills of youths with visual impairments showed that the students' performance in maths was significantly better when using the special software. In addition, parents and teachers reported that use of ICT promoted social inclusion and facilitated schoolwork by students with visual impairment (65, 70). Despite this, the result from one of the descriptive studies with 58 participating teachers who teach students with visual impairment (65) showed that most of them (95%) did not use ICT in the target group.

Students' knowledge in vocabulary and phonic skills was measured in three studies before and after the intervention. The outcomes (40, 54, 55) showed that students with hearing impairments (Table VI) benefited from visual feedback from the computer and multimedia software, e.g. signs created as an avatar, or a combination of images of the words clarified by

lip reading, to facilitate reading. In the fourth intervention study (40), the test found that auditory training using special software was effective, providing improvement in the speech-perception ability for the 17 participating children. However, in the study (41) where two 3D animated interactive software applications for teaching maths and science to deaf students were tested, showed no subject effects.

Discussion

The aim of this review is to investigate type of ICT items and how ICT is being used by students with physical disabilities, and describe benefits of ICT use in school activities. The present study was designed to investigate the use of ICT in school activities among students with *different types* of physical disabilities, such as motor, visual, hearing and communication impairment. This turned out to be necessary in order to obtain a sufficient number of articles for analysis. In addition, this makes it possible to compare the use of ICT between students with a variety of difficulties in participating in school activities. When comparing ICT use, findings in present review show that the type of ICT provides different opportunities depending on the students' impairment group. It can be interpreted that ICT can be seen as a flexible device by compensating for diverse impairments, such as motor, speech, visual and hearing difficulties.

Furthermore, two different purposes appeared when the aims of the interventions of ICT use in the studies were analysed: to compensate for the students' difficulties and to practise with the help of the ICT to increase functional capacity. In both cases ICT has been used as ATD, which has been studied for many years in children with motor impairments (72, 73). However, the results in present study provide some evidence that use of computer and special software improves students' writing ability, in terms of speed, legibility and spelling. Despite the fact that the evidence level is low with small numbers of participants, this is a positive

outcome, as writing is an important activity in school, and a prerequisite for participation in other educational activities. In a study of children without disabilities findings showed that writing by keyboard does not necessarily lead to improvements in the amount of written text (75). This result makes us understand that, for some students with physical disabilities, computer use has specific opportunities to facilitate writing, but computing does not improve writing for all students. The computer as a writing tool has been used for many years, so one unanticipated finding was that only studies in students with motor or speech impairment have been found, but no studies e.g. in students with visual impairment. This is true in spite of findings that indicate that computer and speech synthesis are beneficial tools for students with visual impairment in maths, and should also be beneficial in writing. Are the benefits so obvious and therefore uninteresting to study, or is the tradition in ATD research to focus on product development such as special software and access solutions, rather than to investigate the benefits of the ATDs on students' school performance, such as writing?

In the studies included findings indicate that ICT can be considered to improve writing in speed and script quality for some students. Nevertheless research is still sparse on the benefits of ICT use where writing is an activity in occupations and in today's and future education. MacArthur (76) point out that it is clear that digital skills such as searching for information online, integrating multimedia in writing, and writing online will be important digital skills today and in the future. This research needs to go further and evaluate the new ICT critically but proactively, so systemic improvements can be made in the students' environment and in the development of ICT.

Every effort was made to undertake a thorough review of the literature pertaining to the benefit of ICT use in school activities in students with physical disabilities. However, there are limitations to this review, for example in the selection of keywords. If an assistive technology in a paper was not identified as an ICT or computer-based assistive technology the

paper may not have been incorporated in the search process. Another limitation is that only one of the authors was responsible for the literature search. This may have an impact on the findings, but the results were discussed on several occasions, and the interpretation was done by both authors in collaboration. An explanation regarding sparse research in this area involves findings in an overview of systematic reviews of the effectiveness of ATD use in general by people with disabilities. Their review stated that research on the effectiveness of ATD, and especially evidence concerning ATDs for children and young people, was missing (31) from the literature. The results in present review show that only half of the studies are intervention studies and the other half are of the descriptive type or constitute tests of new products for students with physical disabilities.

The lack of intervention studies is not unexpected since earlier research identified difficulties in including ICT in education (11, 27, 77, 78) and students' dissatisfaction with access to the computer-based ATDs affects the use of ICT in schools (30). Findings in the descriptive studies showed that ICT is not used in schools to the extent that was desirable from the students' perspective (62, 71).

Benefits of ICT use in the interventions studies were often measured from a functional perspective, e.g. decreased spelling errors, improvement in the speech-perception ability, and performance in maths. The functional perspective often assumes that children always choose to use an ATD to compensate for their impairment. However, psychosocial aspects, such as how the ATD influenced children' self-images and peer reactions to the ATD, appeared to be important from the children' perspective (26, 71). Thus findings indicated that psychosocial aspects in relation to performance opportunities are important when children chose whether ATDs were worth using or not. It is documented that outcomes of ATD are depicted as resulting from the interaction among different characteristics: specific

device-type, its users, and their environment (79, 80). A good match of these aspects is essential if the technology may be used, or will be used optimally (79).

Accordingly, difficulties in measuring the outcomes of the ICT use are complex and therefore might be another explanation for why few intervention studies were found. No RCT studies were identified, and only two studies had a control group. Scholars in the area point out the need to develop new methods for assessing research quality in this area (31, 81), especially for situations when control groups or large samples are not possible, i.e. in situations that often occur within ATD outcomes research (82).

Finally, the answer to the question in the introduction is still that ICT has the *potential* to be used for many different types of activities (9, 62, 74). Only a small amount of evidence to support the use of ICT was found to promote the inclusion of students with physical disabilities to achieve equal opportunities in education, thus facilitating school tasks and social interactions. The review found that empirical studies in nature contexts is still missing in benefits of ICT use by students with physical disabilities, mainly in relation to students with visual, hearing and communication impairment.

Conclusion

Despite considerable heterogeneity across the studies, the literature reviewed appears broadly to support that students with physical disabilities benefit from ICT use in schools, regardless of the type of ICT. ICT seems especially beneficial for writing, spelling and communication. For future research it is important to highlight intervention studies to investigate whether ICTs are powerful educational tool for students with physical disabilities, such as motor, visual, hearing and communication impairment – not just as an ATD to compensate for or remediate the impairment for students with physical disabilities. This complexity is also a reason why there is limited evidence of ICT use in schools by students with physical disabilities (31).

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