issues by taking measures to ensure inter-rater reliability. Fifteen out of 30 studies (50%) made some attempt to report on reliability in their study. Seven out of 30 studies (23%) reported on the validity of their study.

A variety of countries were represented in the studies including Australia (n=1), Canada (n=1), Greece (n=4), Israel (n=5), Jordan (n=1), Korea (n=1), Netherlands (n=2), Norway (n=1) Taiwan (n=1), UK (n=5), and USA (n=8).

The studies either focused on the impact technology had on student learning (n=21, 70%), engagement (n=1, 3%) or both (n=8, 27%). The focus of the studies on student learning included literacy (n=16, 53%), numeracy (n=3, 10%), social interactions (n=8, 27%) and 'other' (technology that did not fit into a unified category), which included sequencing (n=1, 3%), visual perception (n=1, 3%), creative thinking (n=1, 3%), and fine motor capability to use a specific technological tool (n=2, 7%). Some studies looked at more than one area, which is reflected in these numbers.

3 Literature Review

The review of the 30 articles is organized into two main subcategories: impact on learning or impact on engagement. Figure 2 gives a visual representation of how the literature review is organized.

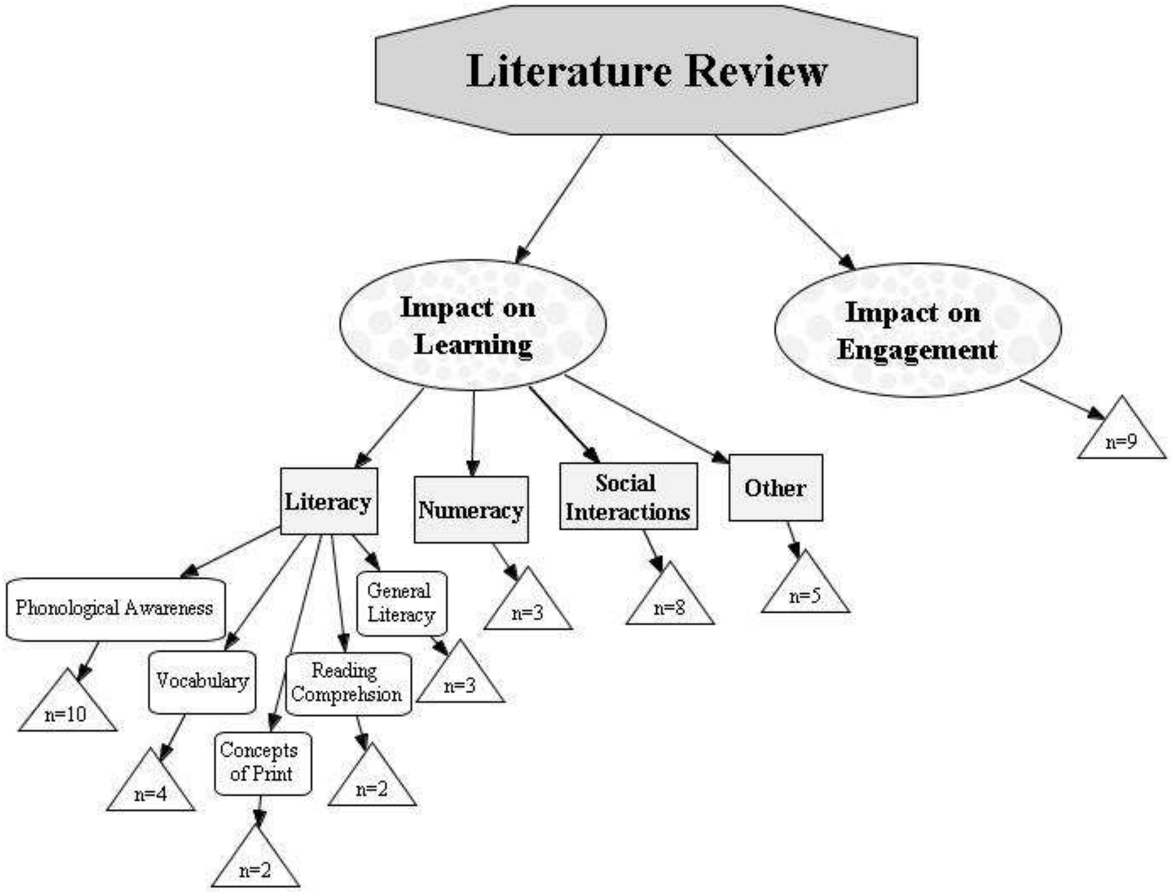

Figure 2: Visual representation of organization of literature review

3.1 Impact of Technology on Learning in Early Childhood Education

3.1.1 Literacy

This category included 16 studies (53%) that described the use of technology to support the development of a wide range of literacy skills including phonological awareness, vocabulary development, concepts of print, reading comprehension and general literacy. Of these 16 studies, several address multiple and overlapping literacy skills which accounts for the total of n=21 as indicated in Figure 2 above.

3.1.1.1Phonological Awareness

Ten studies (33%) addressed phonological awareness or the "ability to analyze the sound structure of language" (p. 172, Maracuso & Rodman, 2011). Specific sub-skills of phonological awareness include the ability to break words into syllables and smaller units of sound, as well as the ability to blend the sounds back together (Maracuso & Rodman, 2011).

Five studies evaluated the use of specific programs, called computer assisted instruction (CAI) in relation to phonological development. These included the web-based program, ABRACADABRA (A Balanced Reading Approach for Canadians Designed to Achieve Best Results for All) (Comaskey, Savage & Abrami, 2009), the CAI programs Early Reading, Primary Reading (Maracuso & Rodman, 2011), and Tutoring Buddy (Volpe, Burns, DuBois & Zaslofsky, 2011), a literacy based PBS program (Penuel et al., 2012) as well as a phonics program presented using an Interactive Whiteboard (Campbell & Mechling, 2009). Five other studies examined the use of e-books and phonological awareness (Wood, Pillinger & Jackson, 2010; Shamir, 2009; Korat, 2009; Korat, Shamir & Arbiv, 2011; Shamir, Korat & Fellah, 2012). An e-book is an electronic version of a printed book with some added features. First, the e-book includes an audio recording of a narrator reading the text. Secondly, the e-book also includes extra visuals and music. Children navigate through the book with forward and back buttons. Finally, most e-books include interactive features such as hotspots that can be clicked to define tricky words or give further insight into the story (Shamir et al., 2012).

In terms of CAI, Comaskey et al. (2009) compared two aspects of the ABRACADABRA program (synthetic and analytic) to determine if they had different effects on phonological development. The synthetic program involved blending and segmenting sounds, while the analytic program focused on rhyme identification and production. They conducted their study with 53 disadvantaged kindergarten students (26 and 27 in each group, respectively). Each group received 13 weeks of 40 fifteen minute sessions in total or, 10 hours of instruction per student. Comaskey et al. (2009) found that the children in the synthetic group showed significant improvement in CV (consonant-vowel) and VC word blending and articulation of final consonants. The children in the analytic group showed significant improvement in articulation of shared rimes. The researchers concluded that the synthetic and analytic programs have qualitatively different effects on children's phonological development.

Maracuso & Rodman (2011) conducted two studies using the CAI program, Early Reading. The Early Reading program was designed to enhance classroom instruction in building a foundation for early literacy skills. The program consists of two levels, each providing computer-assisted practice in literacy skills. The first study used a sample size of 38 preschool students (aged 4-5) who were equally divided into a control and treatment group. The treatment group participated in a total of 200 minutes of CAI over the course of four months. Children used the program independently on a classroom computer. Although both groups experienced some gains in pre-literacy skills, the CAI treatment group had significantly greater gains in phonological awareness than the control group (specifically, sound matching and rhyming).

In their second study, Maracuso & Rodman (2011) targeted kindergarten students who were low performers (based on scoring at least one standard deviation below the norm on the GRADE assessment). Forty-seven students in the treatment group (average age was 5.5 years old) participated in 600 minutes of CAI using the Early Reading program and then potentially progressing to the Primary Reading program (focuses more on early reading skills), while 19 control group students received similar instruction in every other aspect of the kindergarten program. Findings indicated that while both groups made large, significant gains over the school year, the treatment group showed significantly greater gains in phonological awareness total test scores and on the word reading subtest.

Volpe et al. (2011) also focused on at-risk kindergarteners in their study with CAI. They selected four children who were not responding well to the regular kindergarten program. They used a program called Tutoring Buddy, which uses incremental rehearsal (IR) to teach letter sounds. Students were removed from their class to receive the computer instruction in a one-on-one setting with an adult tutor three times per week (for a total of 25 sessions). All four students gained between six and nine letter sounds over the course of the intervention. However, there was no control group in this study so findings should be interpreted with caution.

In a large study by Penuel et al. (2012), teachers of 80 low income preschool classes received training to integrate Public Broadcasting Station (PBS) videos, online games and print-based activities in the classroom for a period of 10 weeks. The materials were either based in literacy (intervention group) or science (control group). Four or five children from each of the 80 classes were randomly selected to complete pre and post tests on literacy skills (for a total of 396 children). The intervention group scored significantly higher than the control group on two phonological subtests: upper letter naming and letter sound awareness. The researchers concluded that supplemental materials from public broadcasting stations hold the potential for improving literacy skills, especially among low income children, although it is not clear which materials influenced the actual change (videos, online games or print-based activities).

Campbell & Mechling (2009) examined the effectiveness of a program used with an Interactive Whiteboard (IWB) targeting phonological awareness. They conducted a small study with three kindergarten children who had learning disabilities. They used a combination of 1:1 sessions and small group sessions (3:1) to teach students letter names and sounds. Each student had certain target letters to learn, and the researchers were interested to see if they would also learn the non-target letters by working in a small group. Students received 34 sessions in total (10 minutes for individual sessions, 15 minutes for group sessions). Findings indicated that the three students increased their letter-sound knowledge for both their own targeted letters in addition to the targeted letters of the other students, but it should be noted that there was no control group in this study. The researchers suggested that the amount of information a student learns may be increased by including non-target stimuli and that the use of IWB was an effective and efficient way to present information.

Use of e-books was another area examined in relation to phonological awareness. Wood, Pillinger & Jackson (2010) re-examined the findings from a study of 80 five and six year old kindergarteners. Forty children were assigned to an intervention group which worked independently with the e-book on the computer, and 40 children were assigned to the control group which worked one-on-one with an adult tutor reading a printed book. Both groups participated in six 15 minute sessions. The researchers created four categories to analyze the interactions of the children: bookbinding (computer/adult primarily reads the book, child is attentive), chiming in (child chimes in to say word(s) with the computer or adult, or repeats them afterwards), supported reading (child does most of reading, but uses the adult/computer to help them with difficult words), and fluent reading (child reads fluently and independently and does not require the adult/computer for support). Children in the e-book group were more likely to engage in bookbinding, while children in the control group were more likely to engage in chiming in with the adult reader. The e-book group (who engaged in more bookbinding) showed greater growth in phonological awareness than the control group who used chiming in. The authors explained that although this may seem counterintuitive (one might think that chiming in is a more advanced skill and thus would correspond to greater gains in phonological awareness), engaging in bookbinding serves an important literacy function in early reading development. Supported reading in both groups was negatively associated with phonological awareness. Fluent reading in the e-book group was negatively associated with phonological awareness, but the opposite was true for the adult-led group. Wood et al. (2010) recommended that there are situations where e-books may be more effective (e.g. with early readers) and situations when adult-led instruction is better (e.g. with more advanced readers), but noted the need for further research.

The remaining studies examining e-books and phonological awareness addressed populations of at-risk children. Shamir (2009) targeted 96 kindergarteners (average age was 6.1 years) of low socioeconomic status (SES). The 46 children in the intervention group engaged in three 35 minute sessions, working in pairs (formed based on friendships) to interact with the e-book on the computer. The control group received regular kindergarten programming. The researchers focused their analysis on the use of two of the activity's features: frequency of activation of e-book hotspots (dictionary, phonological awareness and pictures) and collaborative talk (between participants). The intervention group showed significant improvement between pre and post test scores of emergent literacy. Within these results, collaborative talk was significantly correlated with improved phonological awareness, and activation of dictionary hotspots was significantly correlated with improved word meaning. Shamir (2009) suggested the potential for e-books to help narrow the gap in literacy skills for children with low SES.

Korat (2009) also studied children of low SES and the use of e-books. He examined literacy skills as a function of age (pre-kindergarten and kindergarten) and the number of times students used the e-books (three or five times). Participants included 107 pre-kindergarteners (ages 4.1 to 5.2) and 108 kindergarteners (5.2 to 6.3), randomly assigned to one of three conditions: control, three e-book sessions, or five e-book sessions. The e-book sessions occurred in a separate room where children worked in groups of three, lasting for about 20-25 minutes each. Korat (2009) found that the five session group performed significantly better than the control group (but not the three session group) in a measure of phonological awareness. The same was true for word reading ability. No differences were found between age groups in these areas.

A second study by Korat, Shamir & Arbiv (2011) added another dimension to the original e-book study (Korat, 2009) by adding a group of children who read an e-book with adult support (compared to children in a group who read the e-book without support and the control group who did not have an e-book). Once again, this study targeted children of low SES. The study included 95 kindergarten students (aged 5-6) equally divided between the three conditions (control, e-book, e-book with adult). The four sessions (20 minutes each) took place in a separate room where children worked in pairs. They found the e-book group with adult support performed significantly better on particular subsets of the phonological measure, specifically, opening and closing sounds, as well as word writing, than the e-book and the control groups. The researchers concluded that adult support is important when children work with computers.

Shamir, Korat & Fellah (2012) conducted another study with three groups including a control (34 subjects), e-book (42 subjects) and a printed book read by an adult (34 subjects). They also concentrated on at-risk kindergarteners (aged 5-7) but this time on students who were at risk for having a learning disability. Intervention groups received six sessions of between 20-35 minutes each. The printed book group took place in small groups of three to five students. They found that the e-book group showed significantly higher growth in sub-syllabic segmentation than the other two groups. Note that this study is a mixed study, involving subjects within the age range of this paper, but also slightly out of the age range (up to age 7), so results should be interpreted with some caution.

In summary, with respect to phonological awareness, all of the studies reported that technology use had a positive effect on some aspect of phonological development.

More specifically, two CAI studies and four e-book studies found a significant positive effect on phonological development. Two CAI studies found a positive relationship with phonological development, but these studies had small sample sizes and did not have a control group with which to compare the results. Two studies found that phonological awareness is affected differently depending on the situation: the synthetic and analytic aspects of a CAI program affect different aspects of phonological development, reading an e-book alone vs. a printed book with an adult can have different roles in phonological development. Overall, it appears that both CAI and the use of e-books can support phonological awareness in both typically developing children, as well as at-risk children, although the length of intervention and possibility of adult support need to be considered.

3.1.1.2Vocabulary

The second literacy category, vocabulary development, included four studies (13%) in the areas of e-books and robotics (Korat, 2009; Shamir et al., 2012; Shamir, Korat & Shlafe, 2011; McDonald & Howell, 2012).

Korat's (2009) study with e-books targeted 107 pre-kindergarten and 108 kindergarten students of low SES. Students in the intervention groups engaged in either three or five repeated readings of an e-book for 20-25 minutes per session. Vocabulary levels of low SES children (regardless of age) who read the e-book five times progressed significantly more than those who read the e-book three times and both of these groups performed significantly better than the control.

Shamir et al.'s (2012) study compared three groups of children at risk for learning disabilities (control vs. e-book vs. printed book read by an adult). The e-book and printed book groups received six sessions of 20-35 minutes each. A total of 110 children participated in the study. The e-book group scored significantly higher than both the printed book and control groups with respect to vocabulary. The printed group also scored significantly higher than the control group.

Shamir, Korat & Shlafe's (2011) study compared the vocabulary development of 60 typically developing kindergarten students with 76 kindergarten students at risk for a learning disability (aged 5-7) with the use of e-books. Intervention groups participated in six e-book sessions of 20-35 minutes each. Both typical and at-risk e-book groups scored significantly higher than the control group. In addition, the at-risk group scored significantly higher than the typically developing group which suggested that e-books might be a way to help close the gap in vocabulary development between these two groups.

McDonald & Howell (2012) conducted a study using a robotics program, focusing on several areas, including vocabulary development. The LEGO robotics program *WeDo* had previously only been used with children aged 7 and up. McDonald & Howell (2012) selected a class with 16 students ranging in age from 5.5 to 7 years old.

These children were considered to be of low SES and did not have computer access at home. The classroom had four computers which the children had previously used with commercially produced software programs, basic word processing and Power Point presentations. The researchers used a three phase model (model, explore and evaluate) to introduce and use the robotics program. Their study took place over the course of six weeks, with one visit a week. The model phase took place over two 60 minute sessions (instructed construction of pre-selected robots and basic programming), the explore phase took place over three 60 minute sessions (independent construction of group-selected robots and extended programming) and the final evaluation phase took place over one 90 minute session (prediction of movement of pre-constructed robot and assessment). They found that students showed an improvement in their literacy skills (specifically, use of vocabulary related to robotics and oral language). This was measured through observation, teacher and student surveys, and a student vocabulary assessment. It is important to note that this study did not have a control group with which to compare the intervention group.

Note that these two studies (Shamir et al., 2011 and McDonald & Howell, 2012) are mixed studies, involving students within the age range of this paper, but also slightly out of the age range (up to age 7), so results should be treated with caution.

In summary, all four studies showed an improvement in vocabulary associated with technology use for at-risk children. Three of the studies used quantitative methods with sample sizes over 100 and focused on e-book use. The fourth study, centered on robotics, used qualitative measures to determine an improvement in vocabulary development.

3.1.1.3 Concepts of Print

Two studies (7%) focused on concepts of print which Shamir et al. (2012) describes as “a knowledge of book and text handling as well as the direction in which reading proceeds” (p. 55). Levy (2009) was interested in exploring if children would develop concepts of print through a computer format just as well as with an actual book. She followed 12 children ages 3 to 6 over the course of a year in their home and at their school. Levy found that exposing children to computer texts allowed them to develop confidence in handling print. Specifically, children figured out what both symbols and words meant (despite not yet being able to read) usually through trial and error and were confident in doing so. With paper text, they did not have the same confidence and believed they needed to be taught how to do it. Levy (2009) concluded that using computer texts allowed children to develop a sense of print in a holistic context better than paper texts.

In the other study, Shamir et al. (2012) targeted 110 kindergarten children who were at risk for a learning disability. They compared the use of e-books to a group who read a printed book with an adult. The intervention consisted of six sessions (20-35 minutes in length). Both the e-book and printed book groups showed significant improvement over the control group in terms of concepts of print. However, the e-book group did not show significant improvement over the printed book group, which implied that reading a book with an adult, had the same effect on concepts of print as reading an e-book. The researchers pointed out that children used the e-book on their own and proposed that the use of e-books to develop concepts of print could be particularly valuable when there is a lack of adult availability.

In summary, Shamir et al. (2012) showed a statistically significant positive relationship while Levy (2009) showed a positive association between technology use and the development of concepts of print. Levy's (2009) study was qualitative by design with a small sample size, while the Shamir et al. (2012) used quantitative methods and a large sample size.

3.1.1.4 Reading Comprehension

Two studies (7%) examined reading comprehension. Shamir et al.'s (2011) study compared the use of e-books of 76 at-risk kindergarteners with 60 typical kindergarteners. E-books were used for six sessions of 20-35 minutes in length. The typically developing kindergarteners scored significantly higher than the at-risk group in terms of reading comprehension. However, both groups scored quite low which led the researchers to suggest that comprehension might be taught more effectively with some adult support. These groups could not be compared to the control group whose reading comprehension was not assessed because they had not read the book.

Korat's (2009) study focused on the use of e-books with 107 pre-kindergartners and 108 kindergarteners of low SES. Children received either three or five sessions with the e-books (20-25 minutes each). No difference between the groups was found in terms of reading comprehension. However, age differences were found. Kindergarten aged children did better than the pre-kindergarten aged children, suggesting a developmental aspect to reading comprehension and the use of e-books.

In summary, one study suggested that reading comprehension is not enhanced by the use of e-books, while the other suggested that it might be enhanced for children who are developing typically. An additional consideration is that there may be a developmental aspect and adult support may be needed to teach reading comprehension more effectively.

3.1.1.5 General Literacy

Three studies (10%) were related to general literacy and included emergent reading, writing, and/or oral language skills. Two of these studies used a specific program called PictoPal (which is based in Clicker software) (McKenney & Voogt, 2009; Cviko, McKenney & Voogt, 2011). PictoPal is a program that combines the use of pictures and words to enable students to express themselves in print, even before they are able to read (McKenney & Voogt, 2009). The third study by Huffstetter, King, Onwuegbuzie, Schneider & Powell-Smith (2010) looked at early reading ability in relation to the use of another specific software program from the Headsprout Early Reading program.

McKenney & Voogt (2009) conducted four small studies examining PictoPal and early literacy skills, as well as the impact of adult guidance. Early literacy skills were defined as understanding the functions of written language and the ability to connect spoken and written language. The subjects in each study are kindergarten students and were matched by age, gender and language skills. One subject from each pair was then randomly assigned to the intervention or control group. The first study focused on the child's ability to use the PictoPal program and their gains in early literacy skills. Twenty-one students in the intervention group used the program four times over a period of five weeks (20 minutes for each session). Nineteen students were in the control group. Most learners were able to work independently with the program after some initial help. However, no evidence was found for an improvement in early literacy skills. The second study sought to double the intervention time (8 sessions of 20 minutes each), and use greater adult support with the program (in the form of parent volunteers). Students used semi-open activities only (the first study had closed and open) that were directly related to a current classroom theme. The sample sizes were very small in this study (seven in each group). Students in the intervention group experienced significantly higher gains in early literacy skills than the control group.

In the third study, McKenney & Voogt (2009) kept the length of intervention the same but increased sample sizes to 40 in the intervention group and 39 in the control group. Parent volunteers were used again. This time the control group participated in an alternative language program. Additionally, off-computer classroom activities for the intervention group were added. Again, the intervention group had a significantly higher learning gain than the control group.

In the fourth study, McKenney & Voogt (2009) focused on the types of interactions adults had with the children. Other aspects of the study remained the same as in the third study, except for smaller sample sizes (intervention group had 19 students, control had 18). In this study, the control group showed a significant higher learning gain. The researchers noted that the parent volunteers differed in the kind of feedback they gave to students, and in their ability to interact in a way that encouraged quality products and suggested that the type of adult support has an effect on student learning. They advised that parent volunteers may need training to learn how to best support the students when using PictoPal. Since the results were inconclusive, McKenney & Voogt (2009) also suggested the need for further research.

Cviko, McKenney & Voogt (2011) revisited the PictoPal program. This time the intervention group consisted of 95 children from four classrooms (two junior kindergarten and two senior kindergarten with children aged 3-4, and 4-5, respectively). The control group consisted of 73 children from two other classrooms. The intervention groups used PictoPal for 10-15 minutes a week for eight weeks. Grade 6 students helped the children work with the program. Each week students also participated in an introductory activity in class and a related off-computer activity. Findings indicated that the learning gains in terms of emergent literacy were significantly higher for the intervention group than the control group, suggesting that PictoPal may be an appropriate tool for use with kindergarteners (with the related activities, and a helper at the computer).

Finally, a study by Huffstetter et al. (2010) focused on using a computer software program (Headsprout Early Reading Program) with children of low SES. The Headsprout Early Reading Program consists of a series of online episodes that use explicit instruction and cumulative practice to teach early literacy skills. The intervention and control groups consisted of 31 children each, ranging in age from 4.5 years old to 5.6 years old. The intervention group used the Headsprout Early Reading program, while the control group used a math-based computer program called Millie's Math House. Each child used these programs for 30 minutes daily over the course of 8 weeks. The computers were located in a mobile computer laboratory (school bus fitted with 18 computers). All children engaged in regular literacy activities in the classroom setting. Findings indicated that the early reading ability significantly increased for the intervention group compared to the control group. They also found that although both groups showed improvements in oral language skills, children in the intervention group experienced significantly greater gains. The researchers advised that the Headsprout Early Reading program is an effective intervention for improving early reading and oral language skills of at-risk children.

In summary, the results of these studies of technology use and general literacy were mixed. Of the five PictoPal studies (McKenney & Voogt, 2009, conducted four studies, while Cviko et al., 2011, conducted one), three showed significant improvements in early literacy skills, one showed no improvement and one showed a significant improvement for the control group. Of the two studies not showing significant gains for the intervention group, one had the lowest intervention time (only four sessions of 20 minutes) and the other noticed that the types of interactions of parent volunteers with the students was very inconsistent. This suggests that length of intervention (the significant studies had doubled the intervention time) and the variable of parent volunteers could be having an effect and should be considered in future research. The Huffstetter et al. (2010) study showed a significant improvement in early reading ability with the use of the Headsprout Early Reading Program.

3.1.2 Numeracy

In contrast to the number of studies focusing on literacy (n=16, 53%), only three studies (10%) focused on numeracy. One study was based in robotics (McDonald & Howell, 2012), while the other two examined specific online programs (Fesakis, Sofroniou & Mavroudi, 2011; Fessakis, Gouli & Mavroudi, 2013).

McDonald & Howell (2012) examined the use of a robotics program with sixteen 5-7 year old children of low SES. The program was used in three phases over the course of six weeks (for a total of 6.5 hours). They reported that using a robotics program improved children's numeracy skills (e.g. ability to count, identify colors and shapes and use of positional language). This improvement was inferred based on qualitative observations and the study did not have a control group with which to compare results.

Fesakis et al. (2011) conducted a small case study (four children, aged 5-6 years old) exploring an online program called Monster Exchange, which involved creating a monster and communicating directions over the internet to another class to recreate the monster. Data collection included videos of interactions, children's drawings and recordings of children describing their drawings. According to these qualitative measures, all four children showed improvement in geometry skills (making monsters focused on the use of shapes), although this study did not have a control group for comparison.

Fessakis et al. (2013) examined two programs which required basic programing skills to move a ladybug under a leaf or navigate through a maze. In this case study, 10 kindergarteners (aged 5) engaged in a series of seven activities using an Interactive Whiteboard to display the program (as a group, with teacher support). Based on qualitative analysis of video recordings, the researchers concluded that the programs supported the development of mathematical skills, specifically, 1-to-1 correspondence, counting, number comparison, orientation skills and angle turn concepts. They did not have a control group in their study. They also noted the importance of having adult guidance to complete these activities.

In summary, all three studies suggested an improvement in mathematical skills with technology use. The studies were based on qualitative observations and interviews and did not have control groups. Sample sizes were fairly small, ranging from 4 to 16 subjects. One study mentioned the importance of adult guidance in completing the activities. Such qualitative studies should be interpreted using valid qualitative research standards.

3.1.3 Social Interaction

Eight studies (27%) focused on social interactions of children surrounding the use of technology. Two studies focused on social interactions and robotics programming (McDonald & Howell, 2012; Lee, Sullivan & Bers, 2010), three studies examined social interactions occurring around the computer in the classroom (Lim, 2012; Roberts-Holmes, 2014; Wild, 2011) and three other studies examined social interactions around specific technology or software programs (Sandvik, Smordal & Osterun , 2012; Papadimitriou, Kapaniaris, Zisiadis & Kalogirou, 2013; Fesakis, et al., 2011).

Robotics programming appeared to increase social interaction among students (McDonald & Howell, 2012; Lee, Sullivan & Bers, 2010). McDonald & Howell (2012) used a robotics program with 16 children of low SES over the course of six weeks (6.5

hours) and found that social skills of students improved, specifically with respect to students' ability to interact socially with their peers in the form of turn-taking, sharing ideas and comfort level working in groups. These results were based on qualitative observations, teacher and student surveys and did not include a control group.

Lee, Sullivan & Bers (2010) examined the use of the Creative Hybrid Environment for Robotic Programming (CHERP) in conjunction with the LEGO Mindstorms and social interaction. The study took place over five days with kindergarten students participating in a summer robotics program. The 19 children were divided into two groups (average age was 5.7 years). Nine children were in a group that received structured curriculum lessons (pre-designed, teacher-guided challenges) while the other ten children were in an unstructured curriculum group, following a constructivist approach where they were given free time to explore ideas and concepts on their own. Data was collected using video to verify children's self-reported interactions with others (represented by drawing arrows on a web with pictures of everyone in the classroom). Children in the unstructured group were found to have engaged in significantly more social interactions and peer collaborations than children in the structured group. The researchers suggested that a less structured, "learning by doing" approach might be useful for teachers when integrating technology to help foster peer collaboration.

The following three studies focused on the social interactions that occurred around the computer. Roberts-Holmes (2014) conducted a study to observe peer interactions while working on computers. The selected school had employed a digital media consultant and was considered to be quite advanced in their adoption of technology. Observations and interviews took place over 16 visits (each a half day or full day in length). Fifteen preschoolers from four different classrooms (age 4 to 6 years old) were observed. Robert-Holmes tracked two types of interactions. The first was Sustained Shared Attention (SSA) defined as "mutual attention and focus on the computer tasks, tuning in and showing genuine interest" (p. 8). The second interaction was Sustained Shared Thinking (SST) which is an inter-subjective process involving both cumulative and exploratory talk. The researcher deemed SST to be more cognitively challenging than SSA and thus a higher level of interaction. Findings based on his qualitative observations indicated that when playing together on the computer (engaging in software programs and games) children tended to have a higher level of SSA. However, when engaged in a more constructive activity, such as making mini-movies, children engaged in a higher level of SST. Robert-Holmes speculated that the computer programs were too narrowly focused to encourage a high level of collaborative thinking. These results were based on qualitative observations and did not include a control group.

Wild (2011) also conducted a study examining SST and SSA in terms of technology use. Wild further developed the definition of SST to include clarifying ideas, making suggestions, offering other points of view, asking questions and co-constructing ideas. Wild examined the interactions of pairs of children (5-6 years old) working on a literacy-based computer task compared to pairs working on a paper-pencil task. There were 44 children in the computer group and 43 in the paper-pencil group, from six different schools. The observations took place over the course of six weeks, one session per week (20-25 minutes per session). Based on these qualitative observations, the pairs working on the computer task were found to have a greater number of incidents of both SST and SSA than the paper-pencil pairs.

Lim (2012) was also interested in the social interactions around computers. Lim studied the interactions of 28 children in a full day kindergarten classroom (5-6 years old). Observations took place over a three month period. Students and the two teachers were interviewed. Lim observed that in the computer area, collaborative learning occurred 68.4% of the time whereas in the other activity areas in the classroom, children worked collaboratively for 53.9% of the time. The types of social interactions that occurred in the computer area were the same as those occurring at other activity areas (parallel play, simple verbal conflicts, sociable interactions, knowledge gained through positive interaction process, knowledge gained through negative interaction process and non-verbal communication). Lim recommended that the computer area should not be viewed as an isolating activity and that teachers need to be aware that peers can interact with each other in developmentally meaningful ways, just as they can at any other activity area. These results are based on the qualitative observations of the same group of children playing at various learning centers within their classroom.

The remaining three studies examined the use of specific types of technology or programs and social interactions. Sandvik et al. (2012) conducted a study with five children (aged 5) and noted that the size and portability of an iPad© tablet lent itself naturally to social interactions. The children in this study worked with a teacher and often a peer partner to use two apps. The *See and Say* app is a simple app requiring students to find images in a detail-rich picture. The *Puppet Pals* app is a more constructivist and creative app, allowing children to produce their own unique stories with animation and audio. The children shared their work with the rest of the group by connecting the iPad© to a larger screen. The researchers found that the children helped each other in both partner and full group activities, by cooperating, sharing and participating. These results are based on qualitative analysis of video recordings and transcripts. The study did not have a control group with which to compare the results.

Papadimitriou, Kapaniaris, Zisiadis & Kalogirou (2013) conducted a study with 19 five to six year old children over a period of three weeks. They explored digital storytelling (using a digital camera, webcam and computer) with a focus on social interactions. Their data collection methods included group interviews, observations, notes and video recordings. They found that digital storytelling increased the number of both child-to-child and child-to-teacher social interactions over the course of the intervention. However, there was no control group and these findings are based on qualitative observations.

Fesakis, et al. (2011) conducted a small case study (four children, aged 5-6 years old) exploring an online program called Monster Exchange (creating and giving directions to build a monster). Researchers noted an improvement in collaboration skills among the children over the course of working with this program. Again, these results were based on qualitative methods and did not include a control group for comparison.

In summary, all eight studies reported a positive relationship between technology use and social interactions. However, of the eight studies, seven were based on qualitative research and six did not include a control group with which to compare results. Additionally, six of the studies had sample sizes smaller than 20. Interpretation of these qualitative studies is variable depending on the methodology of these researchers.

3.1.4 Other Technology-Based Studies

Five studies (17%) did not clearly fit into any unified categories. Three of the studies (10%) examined sequencing (Kazakoff & Bers, 2012), visual perception (Chen, Lin, Wei, Liu & Wuang, 2013) and creative thinking (Shawareb, 2011). The remaining two studies (7%) examined the fine motor capability of children to physically navigate a specific technological tool (Panagiotakou & Pange, 2010; Couse & Chen, 2010).

Kazakoff & Bers (2012) explored the use of a robotics program and sequencing skills. Sequencing is an important component in the development of early math and early literacy learning. They were interested in examining whether robotics programming would improve sequencing skills, and the moderating impact of class size, years of teaching experience and teacher's technology competence. Fifty-four children participated in the study from two classes (one small class and one large class) with teachers of varying experience and technological competence. Each class was further subdivided into intervention and control groups. The intervention groups received twice weekly curriculum lessons from the TangibleK robotics program, taught by the kindergarten teacher, for about 60-90 minutes. The control group participated in art during this time. All students completed a pre- and post-test in sequencing skills. The results showed a significant improvement in sequencing skills of the intervention groups, regardless of class size, teacher experience or teacher competence with technology. It is worth noting that the difference in years of teaching experience (one year) and technological competence (one level) may not have been diverse enough to properly assess the relative impact of these variables.

Chen et al. (2013) focused their study on children with developmental delays and visual perception training. They divided 64 children (4-6 year olds, with developmental delays) into one of four groups: multimedia visual perceptual group training, multimedia visual perceptual individual training, paper visual perceptual group training, and a control group (no training). The three intervention groups participated in 40 minute training sessions each week for 14 weeks. The results indicated that all intervention groups showed significant gains in their visual perception skills. However, on closer analysis, only the two multimedia based interventions showed a significant effect that could not be explained by a developmental effect (age-related effect). They also found that the multimedia training group had a greater effect than the individual multimedia training group. Chen et al. (2013) suggested that in the group training, children might have benefited from observing other children. They noted that group treatment might be a solution to the shortage of therapists, service hours and increasing number of children requiring treatment.

Shawareb (2011) examined creative thinking and the use of technology with 76 kindergarten children. He compared the results of a creative thinking test between two classes: one that had a computer in their classroom for 12 weeks (37 children), and the control class which did not have a computer (39 children). The children in the intervention class were given 10-15 minutes daily to work on the computer on their own for 12 weeks (the computer had programs such as Millie's Math House, Bailey's Book House, Sammy's Science House, KidPix, Dr. Seuss's ABC, Thinking' Things I). They were also given 45 minutes in the lab weekly to learn more about how to use computers. He found that the computer group scored significantly higher on the creative thinking test than the control group. However, Shawareb (2011) did not do a pretest to establish that there was no difference between the two groups before the intervention, so these results should be interpreted with caution.

Panagiotakou & Pange (2010) compared the use of a regular mouse and a camera mouse with respect to students' performance on a music activity. A camera mouse uses automatic movement recognition technology to enable the user to control the mouse pointer just by using a part of his/her body that is framed by the camera. Twenty-eight children (4 to 6 years old) worked on either using the regular mouse or camera mouse with a music activity. Students listened to a sound and identified the instrument making the sound. The intervention took place for 15 minutes a week for four weeks. They found that even though the camera mouse was more challenging for the children to use, the children in this group scored significantly better on the music activity than the group using the regular mouse. They speculated that the extra challenge and novelty of using the camera mouse resulted in a higher level of interest and concentration for the children, enabling them to do better on the music activity.

Couse & Chen (2010) conducted a study examining the viability of using tablets in an early childhood environment. They looked at ease of use and quality of self-portrait designs. Forty-one children (3-6 years old) from three preschool classes participated in the study. The children worked in pairs with one researcher in a small, adjoining room from their classroom (each child had their own tablet) for three sessions over two weeks. The researchers examined the level of tablet use (being able to use the functions and solve problems) and found that 98% of children achieved the highest level of use by the second session, suggesting that children can learn to use a tablet very quickly. Children's ability to draw self-portraits with a stylus on a tablet compared to traditional writing tools was also examined. Their teachers compared the electronic self-portrait with one that they had drawn with traditional materials. Teachers ranked their tablet portrait as below expectation, typical or above expectation compared to their paper version. Teachers ranked 20% of the tablet self-portraits as above expectation. Couse & Chen (2010) also conducted a survey with the children and found that 64% of them preferred the tablet over traditional materials. Some of the reasons children gave for this preference was that it was easier to draw on, the colors were brighter and it was easier to erase and change things. For these reasons, the researchers suggested that tablets may be a good technological tool for use in preschool classes.

In summary, three of these five studies indicated that technology use may have a positive influence on sequencing, visual perception skills and possibly, creative thinking skills (although that study should be interpreted with caution due to the lack of a pretest). The remaining two studies had a different focus, being more about if children were able to successfully learn how to use a specific technology and if this helped with their achievement on a music activity and self-portrait drawing, respectively. These studies suggested that children are capable of successfully using a camera mouse and a stylus with a tablet, and that these devices helped them answer more questions correctly on the music activity, and draw a reasonable self-portrait, comparable or better to what they can draw with traditional materials. All of the studies were either quantitative or mixed methods with sample sizes ranging from 28 to 76 subjects.

3.2 Impact of Technology on Engagement in Early Childhood Education

Nine studies (30%) focused on the impact of technology on student engagement in early childhood education. Of the nine studies assessed, four used some type of quantitative tool to measure engagement (Howard et al., 2012; Couse & Chen, 2010; Cviko et al., 2011; McDonald & Howell, 2012). The remaining five studies used qualitative measures to assess engagement (Fesakis et al., 2011; Fessakis, et al., 2013; Papdimitriou et al., 2013; Roberts-Holmes, 2014; Panagiotakou & Pange, 2010). Although many definitions exist for the term engagement, for the purpose of this paper, engagement refers to sustained involvement in learning activities, accompanied by interest and enjoyment (Parsons & Taylor, 2012).

Howard et al. (2012) examined various types of computer use and children's levels of engagement. Twelve schools participated in the study, each of which followed a play-based curriculum. The schools represented a variety of settings (rural, semi-rural, urban), school sizes (ranging from 30-364 children) and class sizes (ranging from 15 to 60 students). Each classroom had at least one desktop computer, eight classrooms had a SMARTboard and11 classes had access to a computer lab. Children ranged in age from three to seven years old. Children's engagement was assessed using the Leuven Involvement Scale to analyze 39 recorded sessions. The mean Leuven score was 3.6, indicating moderate to high levels of engagement. The researchers compared the Leuven scores from the 39 sessions to look for differences based on settings, teacher presence, and the type of use (continuous use where children direct their own learning with the technology, focused use when a particular skill was being taught with technology and enhanced use which lay somewhere in between, the child was given some direction but also had some choice). No significant differences were found in engagement according to the type of use or teacher presence. The only difference the researchers did note was based on group size. Whole class computer activities had marginally significant lower levels of engagement compared to computer activities with smaller groups (Howard et al., 2012).

Two studies noted that the level of engagement increased with the age of the student (Couse & Chen, 2010; Cviko et al., 2011). Couse & Chen (2010) examined the use of tablets with 41 preschoolers (aged 3-6) to assess ease of use and impact on the ability to draw a self-portrait. They noted that based on their qualitative observations, as age increased, so did the length of time engaged with tablet use. Cviko et al. (2011) studied 168 junior and senior kindergarteners using the PictoPal program over the course of 8 weeks. They measured engagement using a rating checklist and found that senior kindergarten (SK) students were significantly more engaged in the computer activity than junior kindergarten (JK) students. The researchers offered a developmental reason for this difference. SK's language use during engagement in computer activities was richer in vocabulary and more socially oriented than that of the JK's. They also noted that both JK and SK engagement with the computer program increased over time, which they speculated was due to increased familiarity and ability to use the program.

McDonald & Howell (2012) worked with 16 students (aged 3-7) of low SES on a robotics program for six weeks (6.5 hours). The program was introduced in three phases (model, explore and evaluate) to help students develop skills in robotics. At the end of the program, they administered a simple survey to determine student's opinions and attitudes towards the program. Students filled in happy, neutral or sad faces to indicate their opinion. They found that students reported high levels of motivation and engagement. The study did not have a control group and although most subjects were within the age range of the review, some were slightly out of range (7 years old), so these results should be interpreted with this in mind.

Fesakis et al. (2011) conducted a small case study with four children (5-6 years old) using an online program called Monster Exchange. The program required students to create a monster and then describe their monster to another class over the internet to see if they could recreate it. In a second study, Fessakis et al. (2014) explored two online programs with 10 students (5 years old), using basic programming skills to direct a ladybug to a leaf, or through a maze. Both studies reported that students appeared highly engaged and motivated, showing enthusiasm and pleasure when working with the programs. These conclusions were based on anecdotal observations (expressions on children's faces, body language, words they said).

Papadimitriou et al. (2013) explored digital storytelling over a period of three weeks with 19 children (5-6 years old). Based on their qualitative data collection methods, including group interviews, observations, notes and video recordings, they reported that children were engaged and motivated throughout all of the activities.

Roberts-Holmes (2014) conducted a study at a preschool that was well known for its adoption of technology. He observed 15 preschoolers (4-6 years old) from four different classrooms over the course of 16 visits. He viewed children during free play at the computers and also while they were working with the digital media consultant to create their own mini movies. Although the focus of his study was on peer interactions, he noted that the collaborative creation of mini-movies was highly engaging for the children. This finding is based on qualitative observation and should be interpreted using standards appropriate to this methodology.

Panagiotakou & Pange's (2010) study compared the use of a regular mouse with a camera mouse to complete a music activity. Twenty-eight children (aged 4-6) participated for 15 minutes a week for four weeks. The researchers observed that the children using the camera mouse were able to engage for longer periods of time. Students used the camera mouse for an average 3.1 minutes, while students used the regular mouse for an average of 1.7 minutes. The researchers also suggested based on qualitative observations that the children appeared to be enjoying using the camera mouse more than the regular mouse.

In summary, all nine studies reported a positive relationship between engagement and technology use, and each was challenged by difficulties of precisely defining and measuring behaviors that indicate engagement. Of the nine studies reported here, four studies use some type of quantitative tool to measure engagement (rating scale, length of time, checklist and student survey), however, the reliability and validity were not reported for any of these tools. The other five studies used qualitative measures (anecdotal evidence and observations) with relatively small sample sizes to report engagement. Seven studies did not have a control group with which to compare the findings. Indeed, there are significant challenges in accurately measuring engagement as it may appear differently in different students and as such is a difficult construct to measure.

3.3 Methodological Challenges

The 30 papers from 2009-2014 that have been reviewed present some interesting findings. However, it is important to address several key methodological concerns including sample size and description, reliability and validity of data collection tools, pedagogy and design issues that may affect the credibility of the results.

3.3.1 Sample Size and Description

Sample size is important as it influences the ability to make generalizations to a larger population. Larger sample sizes have greater potential for generalizability. Of the studies reviewed, 15 (45%) had fairly large sample sizes over 50. On the other hand, 11 studies (34%) had sample sizes of less than 20 students, four of which had sample sizes of less than 10. Seven (21%) had samples sizes between 20 and 50. These are generally considered small sample sizes (Onwuegbuzie & Leech, 2010), although there is some disagreement in this regard. Nikolopoulou (2010) argued that even though sample sizes may be small, when research involves young children and are therefore not easily generalizable, they can still give valuable information for early childhood education settings. Small case studies or qualitative research can provide information and more detailed explanations about phenomena observed. Regardless, it is important to keep in mind that over half of the studies have relatively small sample sizes when considering the results.

In terms of description of samples, seven studies (24%) gave a complete sample description, 19 (63%) a partial description and four (13%) an incomplete description. A detailed description of a sample provide the context of a study and helps researchers make generalizations when the sample size is large enough, or if researchers wish to repeat the study.

3.3.2 Reliability and Validity of Data Collection Tools

The reliability and validity of the data collection tools for the quantitative studies in this literature review was lacking. It is somewhat challenging to have confidence in the data if the tools are not reliable or valid. Of the 13 quantitative studies, only three (23%) reported on both reliability and validity. Five (38%) described validity but not reliability and one (8%) reported on validity but not reliability. Four (31%) of the quantitative studies reported neither.

The mixed methods studies were similarly lacking. Only two of the nine studies (22%) reported both validity and reliability for the tools used. Two other studies (22%) described reliability but not validity. The remaining five studies (56%) did not report either measure.

Three of the eight qualitative studies (38%) explained how they achieved aspects of reliability in their studies. They accomplished inter-rater reliability by having more than one person independently rate/code/organize observations, video recordings and/or transcripts. Of the remaining five qualitative studies, three did not mention reliability or validity, while two acknowledged and explained the limitations and challenges of their study.

3.3.3 Intervention vs. Control Groups

Ideally, quantitative research assessing the impact of technology should have both an intervention and control group. Eleven of the 13 quantitative studies (85%) and six of the nine mixed methods studies (67%) had both intervention and control groups. One qualitative study also used a control and intervention group, which is unusual for qualitative research. The use of a control group gives credibility to the study because it allows for the intervention group to be compared to a baseline, to help determine if the intervention had any effect.

3.3.4 Pedagogy

Pedagogy refers to the strategies that were used with the technology in each study. These details are important for replicating the study, as well as for teasing apart the impact of the device from the impact of instruction. Overall, the studies assess in this review were rigorous with respect to reporting pedagogy used. In 23 studies (76%), the details of the technology and the basics for how it was used were clear. If the technology was used independently, in partners, small groups, or with an adult was mentioned in 20 studies (67%). However, the role of the adult was rarely explained clearly. It is important to understand how the adult engaged with the child or children working with the technology, as the level of support could affect the results.

Three studies also mentioned the use of supplemental materials (although the type of material and how it was used was not necessarily clear), which might also effect the overall impact of technology use. It is difficult to discern if the impact came from the use of the supplemental materials or the technology itself. Not having these details affects the credibility of the studies and makes them difficult to replicate.

3.3.5 Design Issues

Only four studies in this literature review has significant issues with respect to experimental design. Two studies used control and intervention groups that were quite different in size (Cviko et al., 2011 and Maracuso & Rodman, 2011). One study used a posttest experimental design, but did not include a pretest making it impossible to conduct a statistical comparison (Shawareb, 2001). A fourth study (Kazakoff & Bers, 2012) wanted to examine if teacher experience and comfort with technology had any interaction in their robotics and sequencing study. However, the two teachers they chose only differed in their years of teaching experience by one year, and their comfort level by one ranking. These kinds of design issues reduce the credibility of the results reported, however, for the most part they were not present in a majority of the studies reported.

3.4 Summary

Keeping the methodological challenges in mind, some general trends and summaries will be discussed. A brief overview of the findings will be given, followed by a discussion of each subcategory (literacy, numeracy, social interactions, other and engagement)

3.4.1 Overview

Table 1 shows the number of studies in each subcategory and whether the impact of technology was positive, negative or neutral.

Table 1. Summary of Impact of Technology for Early Childhood Education

Area of Impact	Type of Relationship		
	Positive	**Negative**	**Neutral**
Literacy			
Phonological awareness	11		
Vocabulary	4		
Concepts of print	2		
Reading comprehension	1		1
General literacy	4	1	1
Numeracy	3		
Social Interaction	8		
Other	5		
Engagement	9		

Although the review covered 30 studies, many of these studies reported findings in more than one area for a total of 50 results. Ninety-four percent of these results showed a positive relationship, 2% showed a negative relationship, and 4% showing no effect. Note that a disproportionate number of studies (50%) were reported in the area of literacy

3.4.2 Findings in Literacy

Almost all of the studies indicated an improvement in literacy skills with the use of technology. One neutral result was found in the area of reading comprehension where the e-book did not appear to have an effect (Korat, 2009). The other neutral and negative finding came from a series of four studies with the software, PictoPal (McKenney & Voogt, 2009). Two of four studies found a positive relationship between PictoPal use and early literacy skills, while the other two found the neutral and negative relationship. Two themes came up in these studies, as well as in many of the other literacy studies: the need for consideration of the length of time of the intervention and use of adult support. In regards to the type of technology used in these literacy results, 48% used e-books, 44% specific literacy-based programs, 4% robotics and 4% the computer in general. Sixty-eight percent of the literacy studies focused on at-risk children. Of these, 47% were of low SES, 29% at risk for a LD, 6% diagnosed with an LD, 12% low performers and 6% educationally disadvantaged (based on mother's level of education). This indicates a high percentage of at-risk children in literacy studies, compared to the other subcategories (see Table 2).

Table 2. Summary of Technology Impact on Literacy

Area of Impact	**Number of studies**	**Number of studies with at-risk children**
Literacy		
Phonological awareness	11	9
Vocabulary	4	4
Concepts of print	2	1
Reading comprehension	2	2
General literacy	6	1
Numeracy	3	1

Social Interaction	8	1
Other	5	1
Engagement	9	1

One possible reason for the high proportion of studies in literacy is that traditional print-based literacy skills (e.g. alphabet awareness, phonological awareness, concepts of print, vocabulary, reading comprehension) are valued by principals, parents and governments (Lynch & Redpath, 2014; Wohlwend, 2010; Yelland, 2011). This may also help explain the high proportion of at-risk children in literacy based studies, as presumably these populations need to be addressed to improve literacy skills.

It is also worth noting that e-books and literacy-based software are the technology used in 92% of these studies. In the other categories, a wider variety of technologies are represented. However, if the focus is to improve literacy skills, perhaps these technologies are thought to be the most cost effective with the greatest gains. E-books and programs can be used on desktop computers that most classrooms already have and both can be used independently by a child after some brief training, as opposed to requiring the purchase of new technologies (such as iPads©, robotics, webcams) which may require more adult support. Given the positive findings reflected in these studies, literacy skills appear to improving with the use of these technologies.

3.4.3 Findings in Numeracy

All three studies in numeracy suggested an improvement in mathematical skills. One study used robotics technology and two used specific programs. One of the studies targeted children of low SES and one study mentioned the importance of adult guidance.

3.4.4 Findings in Social Interactions

All eight studies reported a positive relationship between technology use and social interactions. Of the eight studies, two used robotics technologies (25%), two used computers in general (25%), one used digital storytelling (12%), one mini-movies (12%), one iPad© with two apps (12%) and one a specific program (12%). Only one study focused on at-risk children of low SES (12%). Generally, these studies supported more open-ended or unstructured activities and found positive social interactions around computer centers.

3.4.5 Findings with Other Technology-Based Studies

These five studies did not fit into any unified category. Each of these studies used a different type of technology: robotics, general computer use, specific program, camera mouse and tablet with stylus. One study focused on at-risk children diagnosed with a developmental delay. Three of the studies indicated a positive influence on sequencing, visual perception skills and creative thinking skills. Two studies suggested that children are capable of successfully using a camera mouse and a stylus with a tablet.

3.4.6 Findings with Engagement

All nine studies reported a positive relationship between engagement and technology use. Of the nine studies, two used specific programs (22%), one robotics (11%), one tablets (11%), one camera mouse (11%), one digital storytelling (11%) and one mini-movies (11%). One study focused on at-risk children of low SES (11%). It was noted that engagement increased with age and familiarity of the program and decreased in whole class computer activities.

4 Conclusions

4.1 Educational Implications

It is clear from the research that technology can have a positive influence on aspects of both learning and engagement in early childhood settings. However, given the wide range of studies and the methodological challenges, it is important for each teacher to make an appropriate fit between the technology tool, their pedagogical approach and the children they are working with. It appears from the research that a wide variety of possibilities exist in terms of types of technology use (desktops computers with specific programs, e-books, tablets, video cameras, interactive whiteboards and robotics), how the technology is used (individually, partners, small