Improving Early Literacy Skills Using Technology at Home

Haya Shamir, Claudia Miner, Ann Izzo, Kathryn Feehan, Erik Yoder, and David Pocklington
Waterford Research Institute, Sandy, Utah, USA
Email: {hayashamir, claudiaminer, annizzo, kathrynfeehan, erikyoder, davidpocklington}@waterford.org

***Abstract*—This study explored the impact of computer-assisted instruction on the literacy skills of young learners. Pre-kindergarten students were randomized into either a computer-adaptive reading (experimental) condition using the Waterford Early Reading Program (ERP) or a computer-adaptive math and science (control) condition using the Waterford Early Math and Science Program (EMS). Students used their respective programs at home in thirteen of the most rural school districts in Utah. The Waterford Assessments of Core Skills (WACS) was administered at the beginning and end of the program to assess students' literacy skills across multiple strands. At the end of the program year, students who used the computer-adaptive reading program significantly outperformed their control counterparts on Overall WACS scores; furthermore, students who used ERP outperformed their control counterparts on literacy strands of the assessment. The improvement was seen across demographics, including socioeconomic status, whether students attended another preschool, ethnicity, and active special education status. These findings indicate that computer-assisted instruction improves students' early literacy skills after one year in the program and prepares them for kindergarten.**

***Index Terms*—early learning, computer-assisted instruction, literacy**

I. Introduction

A child's first years play a dramatic role, laying out the groundwork for the acquisition of language and word learning skills, with discrepancies in reading competency sometimes appearing before kindergarten [1]. By the time a child enters first grade, meaningful differences in reading technique and achievement are already present [2]. Often, failure to master early linguistic principles can foretell more pronounced problems later in a student's academic career. Students who have not mastered these foundational skills may find themselves struggling with new lessons that build on knowledge that the students do not have. This can lead to a "Matthew effect," where the only students who are prepared to succeed are those who were already succeeding in the first place [3].

There is evidence to suggest the education system in the United States may be failing the same students who need it most. Ten years ago, over a third of fourth graders received the lowest grade for reading comprehension on the NAEP reading skills test [4]. As of 2013, that metric remained at 32% [5]. Historic efforts, such as the No Child Left Behind act, have failed to improve education in a meaningful fashion [6], [7]. From 2013 to 2015 benchmarks for the NAEP were stagnant across a wide range of demographic achievement gaps, with average reading scores for fourth graders showing little to no growth [5]. Improving the efficacy of early reading instruction continues to be a significant issue in education.

Research has shown that investing in childhood development at the preschool age has the highest return on investment, especially for underprivileged students [8]. Because of this research, four-fifths of states have attempted to implement one variation or another on universal pre-kindergarten. As of 2010, approximately one-half of children attended preschool at age three, and around three-quarters of children attended preschool by age four [9]. However, the cost of traditional preschool can be prohibitive, especially in an environment where school budgets are already stretched thin meeting the needs of existing K-12 programs. The cost of a traditional classroom-based pre-kindergarten program varies across different states, though estimates range from $5,000 per child for a half day to $10,000 per child for a full day [10].

The high cost of traditional preschool programs aside, a meta-analysis of preschool interventions showed that in general they can provide positive effects, especially in cognitive skills such as reading and math, though the outcome and effectiveness of the programs varied widely across different studies [11].

With these limitations in mind, learning at home is an available and viable alternative. From birth until high school graduation only a small portion, around 13%, of a child's waking hours are spent in school [12], [13]. Time available at home is an untapped resource for addressing the limitations of traditional educational settings [12].

Technology can provide an efficient curriculum with individualized instruction in a home-based learning environment [14]. Computer-Assisted Instruction (CAI) presents engaging lessons, making full use of entertaining and interactive media. CAI can provide timely and appropriate feedback to responses. Research has shown that use of CAI instruments has been associated with significantly improved learning outcomes [15], and can benefit younger and sensitive populations particularly [16]. The importance of appropriate academic supervision is difficult to overstate. A successful home-based learning environment also requires a robust support organization.

Manuscript received December 25, 2018; revised March 15, 2019.

doi: 10.18178/ijlt.5.3.191-197

Keeping parents and caregivers involved and engaged in a student's education, as well as helping them to manage available time efficiently, is essential.

Research has indicated that CAI can have a powerful impact on young learners [17]. It is the hypothesis of this study that use of an adaptive, individualized reading curriculum will improve the early literacy skills of pre-kindergarten students.

II. Methods

A. Participants

An initial sample (N = 864) of four-year-old pre-kindergarten children was collected from thirteen Utah school districts located in rural areas during the 2014-2015 school year. To participate in the program, parents and caregivers committed their children to using their assigned curriculum for fifteen minutes per day, five days per week. Most students had a parent or guardian with either some college (46.8%) or a bachelor's degree (25.1%). 54.4% of the sample lived below 185% of the poverty line.

B. Materials

1) Waterford Assessments of Core Skills (WACS)

An adaptive assessment that was administered at the beginning and end of the school year designed to assess eleven key pre-literacy and reading skills. Initial content validity for WACS was established against state and national standards for the eleven subtests. Item calibration was performed using Item Response Theory. To establish concurrent validity and predictive validity student performance on WACS was compared to performance on five commonly used standardized tests also measuring early reading skills; all correlations between tests are significant, ranging from r = .41 to r = .78 (median r = .63). Additional analyses indicate that WACS is internally consistent and has strong test-retest reliability (r = .90).

2) Waterford Early Learning (WEL)

The program offers a comprehensive, computer-adaptive curriculum for either reading and pre-reading or math and science for pre-kindergarten through second grade students. The software presents a wide range of multimedia-based activities in an adaptive sequence tailored to each student's initial placement and his or her individual rate of growth throughout the complete reading curriculum.

C. Procedure

Using random selection, pre-kindergarten students were assigned to use either the Waterford Early Reading Program (experimental) or the Waterford Early Math and Science Program (control) as part of the UPSTART program. Students used their assigned curriculum for 15 minutes per day, 5 days per week throughout the 2014-2015 school year. Usage was tracked and monitored weekly by personal care representatives and school district liaisons. Students were administered the WACS reading assessment at the beginning and end of the 2014-2015 school year.

Assessment data was missing for 341 students. 211 had pretest scores but lacked posttest scores: 104 were in the control condition and 107 were in the treatment condition. 71 students had posttest scores but lacked pretest scores: 37 students were in the control condition and 34 were in the treatment condition. 59 students were missing both pretest and posttest scores: 29 were in the control condition and 30 were in the treatment condition.

Participants without complete data were removed from analysis, resulting in a 39.47% overall attrition rate, and a differential attrition rate of 1.97%. The final sample (N = 523) consisted of students with both pre- and posttest data, randomly assigned to a treatment-only condition (N = 273) or a control-only condition (N = 250).

III. Results

A. Analysis of Covariance (ANCOVA)

To examine the efficacy of the Waterford Early Reading Program (ERP) on students' early literacy skills, an ANCOVA was conducted on WACS posttest scores covarying for WACS pretest scores (see Table I).

1) Overall

Analysis of Overall end of year scores, while covarying for beginning of year scores, revealed a statistically positive effect, $F(1, 520) = 23.30$, $p < .01$, due to higher end of year scores made by students in the experimental group than by students in the control group.

2) Blending

Analysis of Blending end of year scores, while covarying for beginning of year scores, revealed a statistically positive effect, $F(1, 516) = 9.74$, $p < .01$, due to higher end of year scores made by students in the experimental group than by students in the control group.

3) Initial sound

Analysis of Initial Sound end of year scores, while covarying for beginning of year scores, did not reveal a significant effect between students in the experimental group and students in the control group, $F(1, 516) = 2.90$, $p = .089$; however, students in the experimental group had slightly higher scores than students in the control group.

4) Letter sound

Analysis of Letter Sound end of year scores, while covarying for beginning of year scores, revealed a statistically positive effect, $F(1, 518) = 35.00$, $p < .01$, due to higher end of year scores made by students in the experimental group than by students in the control group.

5) Letter recognition

Analysis of Letter Recognition end of year scores, while covarying for beginning of year scores, revealed a statistically positive effect, $F(1, 519) = 13.67$, $p < .01$, due to higher end of year scores made by students in the experimental group than by students in the control group.

6) Listening comprehension

Analysis of Listening Comprehension end of year scores, while covarying for beginning of year scores, did not reveal a significant effect between students in the experimental group and students in the control group, $F(1, 361) = 3.08$, $p = .080$; however, students in the

experimental group had slightly higher scores than students in the control group.

7) Vocabulary

Analysis of Vocabulary end of year scores, while covarying for beginning of year scores, did not reveal a significant effect between students in the experimental group and students in the control group, $F(1, 515) = 0.66$, $p = .417$; however, students in the experimental group had slightly higher scores than students in the control group.

B. WACS Scores - Demographics

Further analysis was conducted to examine the impact of demographics on Overall, Blending, Letter Sound, and Letter Recognition posttest scores using pretest scores as a covariate (see Tables II-V). The Benjamini-Hochberg correction for multiple comparisons was applied to all analyses within each domain.

1) Overall

a. 185% poverty level

No significant interaction was found for the effects of poverty level and ERP on posttest Overall scores, $F(1, 518) = 1.64$, $p = .201$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Overall scores. Students above and below 185% of the poverty line in the experimental group significantly outperformed students in the control group.

b. Gender

No significant interaction was found for the effects of gender and ERP on posttest Overall scores, $F(1, 518) = 2.33$, $p = .128$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Overall scores. Male and female students in the experimental group significantly outperformed students in the control group.

c. Other preschool

No significant interaction was found for the effects of attending another preschool and ERP on posttest Overall scores, $F(1, 518) = 0.19$, $p = .666$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Overall scores. Students who did not attend another preschool and students who attended another preschool in the experimental group significantly outperformed students in the control group.

d. Ethnicity

No significant interaction was found for the effects of ethnicity and ERP on posttest Overall scores, $F(4, 510) = 0.49$, $p = .745$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Overall scores. Caucasian students in the experimental group significantly outperformed Caucasian students in the control group. Scores for Hispanic students in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

e. Special education status

No significant interaction was found for the effects of active special education status and ERP on posttest Overall scores, $F(1, 518) = 1.26$, $p = .262$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Overall scores. Students without active special education status and students with active special education status in the experimental group significantly outperformed students in the control group.

2) Blending

a. 185% Poverty Level

No significant interaction was found for the effects of poverty level and ERP on posttest Blending scores, $F(1, 514) = 0.23$, $p = .633$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Blending scores. Students below 185% of the poverty line in the experimental group significantly outperformed students in the control group. Scores for students above 185% of the poverty line in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

b. Gender

No significant interaction was found for the effects of gender and ERP on posttest Blending scores, $F(1, 514) = 0.27$, $p = .601$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Blending scores. Female students in the experimental group significantly outperformed students in the control group. Scores for male students in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

TABLE I. WACS END OF YEAR SCORES CONTROLLING FOR BEGINNING OF YEAR SCORES

	Experimental			Control				
	M	SD	*N*	*M*	SD	*N*	*p*	*g*
Overall	2597.90	373.85	273	2456.53	372.44	250	.00**	0.42
Blending	2669.03	722.27	270	2478.63	684.54	249	.00**	0.27
Initial Sound	2537.51	267.00	270	2499.37	248.54	249	.09	0.16
Letter Sound	2529.91	558.38	272	2254.86	531.94	249	.00**	0.52
Letter Recognition	2016.84	220.07	273	1948.41	227.57	249	.00**	0.32
Listening Comprehension	2799.08	1118.57	173	2593.70	1199.91	191	.08	0.18
Vocabulary	2784.81	656.44	270	2737.86	666.79	248	.42	0.06

*$p < .05$, **$p < .01$

TABLE II. OVERALL WACS END OF YEAR SCORES BY DEMOGRAPHICS

	Experimental			Control				
	M	SD	*N*	*M*	SD	*N*	*p*	*g*
185 % Poverty								
Above	2624.09	365.58	118	2515.95	376.15	126	.01*	0.22
Below	2578.38	376.17	155	2395.63	355.42	124	.00**	0.40
Gender								
Female	2629.05	355.70	141	2442.70	396.28	115	.00**	0.39
Male	2564.91	385.60	132	2468.03	351.98	135	.02*	0.21
Other Preschool								
No Other Preschool	2576.03	401.85	119	2449.28	372.74	114	.00**	0.25
Another Preschool	2614.80	351.29	154	2462.60	372.86	136	.00**	0.34
Ethnicity								
Caucasian	2624.48	358.80	243	2483.10	365.82	221	.00**	0.41
Hispanic	2401.61	424.90	19	2304.63	338.36	19	.36	0.09
Special Education Status								
No Active Special Education Status	2602.98	375.34	256	2468.22	363.34	236	.00**	0.39
Active Special Education Status	2526.71	327.69	17	2252.96	386.87	14	.02*	0.20

*$p < .05$, **$p < .01$

c. Other preschool

No significant interaction was found for the effects of attending another preschool and ERP on posttest Blending scores, $F(1, 514) = 0.79$, $p = .375$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Blending scores. Students who did not attend another preschool in the experimental group significantly outperformed students in the control group. Scores for students who attended another preschool in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

d. Ethnicity

No significant interaction was found for the effects of ethnicity and ERP on posttest Blending scores, $F(4, 506) = 1.04$, $p = .388$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Blending scores. Caucasian students in the experimental group significantly outperformed Caucasian students in the control group. Scores for Hispanic students in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

e. Special education status

No significant interaction was found for the effects of active special education status and ERP on posttest Blending scores, $F(1, 514) = 0.86$, $p = .355$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Blending scores. Students without active special education status in the experimental group significantly outperformed students in the control group. Scores for students with active special education status in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

3) Letter sound

a. 185% poverty level

No significant interaction was found for the effects of poverty level and ERP on posttest Letter Sound scores, $F(1, 516) = 0.97$, $p = .326$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Letter Sound scores. Students above andbelow 185% of the poverty line in the experimental group significantly outperformed students in the control group.

TABLE III. BLENDING WACS END OF YEAR SCORES BY DEMOGRAPHICS

	Experimental			Control				
	M	SD	*N*	*M*	SD	*N*	*p*	*g*
185 % Poverty								
Above	2729.99	684.40	118	2560.91	721.30	125	.06	0.17
Below	2622.32	747.02	152	2394.96	634.86	124	.01**	0.24
Gender								
Female	2685.59	704.55	141	2462.56	677.15	114	.01*	0.22
Male	2651.05	742.76	129	2492.10	692.78	135	.06	0.17
Other Preschool								
No Other Preschool	2670.88	715.62	118	2420.96	661.71	114	.01**	0.24
Another Preschool	2667.86	729.74	152	2527.04	699.83	135	.09	0.15
Ethnicity								
Caucasian	2694.42	702.92	240	2513.20	688.76	220	.01**	0.25
Hispanic	2473.85	944.77	19	2181.40	590.41	19	.19	0.11
Special Education Status								
No Active Special Education Status	2681.43	729.88	256	2504.63	689.90	236	.01**	0.25
Active Special Education Status	2439.37	525.27	14	2009.96	391.85	13	.11	0.14

*$p < .05$, **$p < .01$

TABLE IV. LETTER SOUND WACS END OF YEAR SCORES BY DEMOGRAPHICS

	Experimental			Control				
	M	SD	*N*	*M*	SD	*N*	*p*	*g*
185 % Poverty								
Above	2575.46	543.65	118	2340.41	506.60	125	.00**	0.31
Below	2495.01	566.58	154	2168.61	542.42	124	.00**	0.45
Gender								
Female	2557.28	543.79	141	2273.01	551.91	114	.00**	0.37
Male	2500.45	573.27	131	2239.53	515.85	135	.00**	0.35
Other Preschool								
No Other Preschool	2490.70	571.91	119	2241.77	529.11	114	.00**	0.31
Another Preschool	2560.41	547.51	153	2265.90	535.99	135	.00**	0.41
Ethnicity								
Caucasian	2560.42	551.22	242	2275.63	537.37	220	.00**	0.51
Hispanic	2282.17	585.34	19	2219.49	512.13	19	.71	0.03
Special Education Status								
No Active Special Education Status	2527.30	565.56	256	2262.73	530.32	236	.00**	0.49
Active Special Education Status	2571.75	437.85	16	2111.95	544.76	13	.02*	0.20

*$p < .05$, **$p < .01$

b. Gender

No significant interaction was found for the effects of gender and ERP on posttest Letter Sound scores, $F(1, 516) = 0.06$, $p = .803$. Simple effects analysis showed statistically significant positive effects for the use of ERP on the Letter Sound scores. Male and female students in the experimental group significantly outperformed students in the control group.

c. Other preschool

No significant interaction was found for the effects of attending another preschool and ERP on posttest Letter Sound scores, $F(1, 516) = 0.24$, $p = .626$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Letter Sound scores. Students who did not attend another preschool and students who attended another preschool in the experimental group significantly outperformed students in the control group.

d. Ethnicity

No significant interaction was found for the effects of ethnicity and ERP on posttest Letter Sound scores, $F(4, 508) = 0.45$, $p = .771$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on the Letter Sound scores. Caucasian students in the experimental group significantly outperformed Caucasian students in the control group. Scores for Hispanic students in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

e. Special education status

No significant interaction was found for the effects of active special education status and ERP on posttest Letter Sound scores, $F(1, 516) = 0.91$, $p = .339$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Letter Sound scores. Students without active special education status and students with active special education status in the experimental group significantly outperformed students in the control group.

4) Letter recognition

a. 185% poverty level

No significant interaction was found for the effects of poverty level and ERP on posttest Letter Recognition scores, $F(1, 517) = 1.99$, $p = .159$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on Letter Recognition scores. Students below 185% of the poverty line in the experimental group significantly outperformed students in the control group. Scores for students above 185% of the poverty line in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

b. Gender

No significant interaction was found for the effects of gender and ERP on posttest Letter Recognition scores, $F(1, 517) = 0.35$, $p = .554$. Simple effects analysis showed statistically significant positive effects for the use of ERP on the Letter Recognition scores. Male and female students in the experimental group significantly outperformed students in the control group.

c. Other preschool

No significant interaction was found for the effects of attending another preschool and ERP on posttest Letter Recognition scores, $F(1, 517) = 1.06$, $p = .303$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Letter Recognition scores. Students who did not attend another preschool and students who attended another preschool in the experimental group significantly outperformed students in the control group.

d. Ethnicity

No significant interaction was found for the effects of ethnicity and ERP on posttest Letter Recognition scores, $F(4, 509) = 0.34$, $p = .851$. Simple effects analysis showed a statistically significant positive effect for the use of ERP on the Letter Recognition scores. Caucasian students in the experimental group significantly outperformed Caucasian students in the control group. Scores for Hispanic students in the experimental group were slightly higher than those of students in the control group, but the difference was not significant.

e. Special education status

A significant interaction was found for the effects of active special education status and ERP on posttest Letter

Recognition scores, $F(1, 517) = 4.45$, $p < .05$. Simple effects analysis showed statistically significant positive effects for the use of ERP on Letter Recognition scores. Students without active special education status and students with active special education status in the experimental group significantly outperformed students in the control group.

TABLE V. LETTER RECOGNITION WACS END OF YEAR SCORES BY DEMOGRAPHICS

	Experimental			Control				
	M	SD	*N*	*M*	SD	*N*	*p*	*g*
185 % Poverty								
Above	2026.35	183.12	118	1982.51	205.31	125	.10	0.14
Below	2009.77	244.46	155	1913.83	242.32	124	.00**	0.33
Gender								
Female	2041.25	193.44	141	1963.75	201.38	114	.00**	0.25
Male	1990.92	242.82	132	1935.31	246.59	135	.03*	0.19
Other Preschool								
No Other Preschool	2028.93	250.15	119	1939.28	240.86	114	.00**	0.28
Another Preschool	2007.45	194.47	154	1956.18	216.34	135	.04*	0.18
Ethnicity								
Caucasian	2021.44	209.73	243	1955.44	224.57	220	.00**	0.30
Hispanic	1964.15	331.11	19	1915.54	252.05	19	.48	0.06
Special Education Status								
No Active Special Education Status	2016.96	223.44	256	1957.05	224.55	236	.00**	0.28
Active Special Education Status	2016.87	166.22	17	1789.08	201.75	13	.00**	0.25

*$p < .05$, **$p < .01$

IV. DISCUSSION

Results supported the study's hypothesis that CAI bolstered reading skills for young learners. Students who used ERP benefited from improved learning outcomes on most measured skills. Students in the experimental group had higher end of year scores while covarying for beginning of year scores than students in the control group on all strands of the assessment. These findings offer support for the use of computer-assisted instruction by pre-kindergarten students to improve foundational reading and literacy skills.

Learning basic literacy skills is a critical component of any education; however, not all students have the capability to attend a traditional preschool program. For more students to excel in early literacy skills, high-quality but affordable pre-kindergarten instruction is necessary. Proposed solutions should aim for novel, or even revolutionary, approaches, but they still need to provide concrete, methodologically-sound evidence of efficacy. The right technology, like ERP as demonstrated in this study, can transform a child's home into a productive learning environment and provide an alternative method of preparing students for kindergarten that is engaging and cost effective. Across demographics, students' literacy scores improved after using ERP in the home, preparing students for kindergarten through computer-assisted instruction.

Early childhood education is necessary so that each student can achieve their own unique potential. The successful implementation of technology, as shown empirically in this study, makes it possible to successfully deliver crucial education in settings where traditional preschool may not be practical. Before students begin kindergarten, an adaptive CAI curriculum can set students on the path to academic success.

REFERENCES

[1] A. Weisleder and A. Fernald, "Talking to children matters: Early language experience strengthens processing and builds vocabulary," *Psychological Science*, vol. 24, no. 11, pp. 2143-2152, 2013.

[2] J. E. Herbers, J. J. Cutuli, L. M. Supkoff, D. Heistad, C. K. Chan, E. Hinz, and A. S. Masten, "Early reading skills and academic achievement trajectories of students facing poverty, homelessness, and high residential mobility," *Educational Researcher*, vol. 41, no. 9, pp. 366-374, 2012.

[3] J. Ricketts, R. Sperring, and K. Nation, "Educational attainment in poor comprehenders," *Frontiers in Psychology*, vol. 5, p. 445, 2014.

[4] S. Aud, S. Wilkinson-Flicker, P. Kristapovich, A. Rathbun, X. Wang, and J. Zhang, The Condition of Education 2013. NCES 2013-037. National Center for Education Statistics, 2013.

[5] G. Kena, W. Hussar, J. McFarland, C. de Brey, *et al*., The Condition of Education 2016. NCES 2016-144. National Center for Education Statistics, 2016.

[6] S. V. Chappell and M. Cahnmann-Taylor, "No child left with crayons: The imperative of arts-based education and research with language 'minority' and other minoritized communities," *Review of Research in Education*, vol. 37, no. 1, pp. 243-268, 2013.

[7] E. Davidson, R. Reback, J. E. Rockoff, and H. L. Schwartz, "Fifty ways to leave a child behind: Idiosyncrasies and discrepancies in states' implementation of NCLB," *Educational Researcher*, vol. 44, no. 6, pp. 347-358, 2015.

[8] G. J. Duncan and K. Magnuson, "Investing in Preschool Programs," *Journal of Economic Perspectives*, vol. 27, no. 2, pp. 109-132, 2013.

[9] National Institute for Early Education Research (2012). Estimated Participation and Hours in Early Care and Education by Type of Arrangement and Income at Ages 2 to 4 in 2010. [Online]. Available: http://nieer.org/wp-content/uploads/2016/08/ECE20Participation20Estimations.pdf

[10] National Institute for Early Education Research (2011). Preschool Education as an Educational Reform: Issues of Effectiveness and Access [Online]. Available: http://nieer.org/wp-content/uploads/2016/08/NRC20Preschool20Report20Rev20920262011.pdf

[11] G. Camilli, S. Vargas, S. Ryan, and W. S. Barnett, "Meta-analysis of the effects of early education interventions on cognitive and social development," *Teachers College Record*, vol. 112, no. 3, pp.

579-620, 2010.
[12] Y. Anders, H. G. Rossbach, S. Weinert, S. Ebert, S. Kuger, S. Lehrl, and J. von Maurice, "Home and preschool learning environments and their relations to the development of early numeracy skills," *Early Childhood Research Quarterly*, vol. 27, no. 2, pp. 231-244, 2012
[13] J. H. Walberg. (2003). Improving educational productivity. Publication Series No. 1. Philadelphia: Laboratory for School Success [Online]. Available: https://files.eric.ed.gov/fulltext/ED483038.pdf
[14] C. Christensen, C. Johnson, and M. Horn, *Disrupting Class: How Disruptive Innovation will Change the Way the World Learns*, New York, NY: McGraw Hill, 2008.
[15] S. Higgins, Z. Xiao, and M. Katsipataki, "The impact of digital technology on learning: A summary for the education endowment foundation," Durham, UK: Education Endowment Foundation and Durham University, 2012.
[16] A. M. Fish, X. Li, K. McCarrick, S. T. Butler, B. Stanton, G. A. Brumitt, N. P. Bhavnagri, T. Holtrop, and T. Partridge, "Early childhood computer experience and cognitive development among urban low-income preschoolers," *Journal of Educational Computing Research*, vol. 38, pp. 97-113, 2008.
[17] P. Macaruso and A. Walker, "The efficacy of computer assisted instruction for advancing literacy skills in kindergarten children," *Reading Psychology*, vol. 29, pp. 266-287, 2008.

Haya Shamir was born in Haifa, Israel. Received her PhD from University of Notre Dame in 2002. She has been working at Waterford Research Institute, based in Sandy, Utah, since 2005, currently serves as chief scientist. She has published research in multiple journals throughout her career.

Claudia Miner is Chief UPSTART Officer at the Waterford Institute. She has been with the program since its inception in 2008 and has served as Project Director for both the UPSTART i3 Validation Grant and the UPSTART EIR Expansion grant. She received her Ph.D. from Washington State University.

Ann Izzo has 30 years of experience in Customer Service Management and has worked at the Waterford Institute since 2009. She is responsible for the development of the UPSTART support program that ensures usage of all participants. She currently serves as UPSTART Managing Director.

Kathryn C. Feehan was born in York, Pennsylvania. She graduated with honors from the University of Pittsburgh with a Bachelor of Science in Psychology and Sociology, and she is currently working on her Master of Science in Education at Duquesne University. She currently works at Waterford Research Institute based in Sandy, Utah.

Erik H. Yoder was born in Greenwich, Connecticut, USA. He earned a Bachelor of Arts in psychology and Norwegian from St. Olaf College, Northfield Minnesota, USA, in 2012. He is employed as a research assistant at Waterford Research Institute, based in Sandy, Utah, US.

David B. Pocklington was born in Southfield, MI in 1987. Graduated with MS, Experimental Psychology, Rivier University, Nashua, NH, 2014. He currently works as a research assistant for Waterford Research Institute, based in Sandy, UT. Research interests include computer-assisted instruction and assessment.

