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Effectiveness of Two Keyboarding Instructional Approaches on the Keyboarding Speed, Accuracy, and Technique of Elementary Students

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Abstract

Background: Keyboarding skill development is important for elementary students. Limited research exists to inform practice on effective keyboarding instruction methods.

Method: Using a quasi-experimental design, we examined the effectiveness of Keyboarding Without Tears® (n = 786) in the experimental schools compared to the control schools who used the district standard instructional approach of free web-based activities (n = 953) on improving keyboarding skills (speed, accuracy, and technique) in elementary students.

Results: The results showed significant improvements in keyboarding speed and accuracy in all schools for all grades favoring the experimental schools compared to the control schools. Significant differences in improvements in keyboarding technique were found with large effect sizes favoring the experimental schools for kindergarten to the second grade and small effect sizes favoring the control schools for the third to fifth grade.

Conclusion: Professionals involved in assisting with keyboarding skill development in children are recommended to begin training in these skills in early elementary grades, especially to assist in proper keyboarding technique development. While using free web-based activities are beneficial to improving keyboarding speed and accuracy, as well as keyboarding technique, using a developmentally-based curriculum, such as Keyboarding Without Tears®, may further enhance improvements in the keyboarding skills of elementary students.

Keywords

elementary education, interactive learning environments, teaching/learning strategies, human computer interface

Cover Page Footnote

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Credentials Display

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The academic benefits of effective student keyboarding skills have been demonstrated consistently over time. Keyboarding improves children's reading and writing skills (Cantalupi, 1991) and their organization of reading and writing thoughts, as well as legible writing (Whithaus, Harrison, & Midyette, 2008) and keyboarding proficiency, which are essential for writing success in upper-level academic and professional settings (van Weerdenburg, Tesselhof, & van der Meijden, 2019). Other documented benefits of keyboarding are improvements in spelling, speed, vocabulary, listening, Scholastic Achievement Test scores, attention during keyboarding, confidence, and motivation (Ashburner, Ziviani, & Pennington, 2012; Horne, Ferrier, Singleton, & Read, 2011; van Weerdenburg et al., 2019). In addition, keyboarding not only has been linked to academic benefits but also is a preferred means of writing by students. When compared to handwriting, keyboarding was perceived by students of various ages as faster and more efficient to edit (Ashburner et al., 2012; Whithaus et al., 2008).

Keyboarding Skills in Schools

In educational settings, keyboarding skills are required for two primary functions: computer-based testing and writing and composing (Niepert, 2018; Poole & Preciado, 2016; van Weerdenburg et al., 2019). This use of computer-based testing without adequate foundational keyboarding training can be problematic. In a study by Poole and Preciado (2016), teachers believed that "although the computerized tests do not have published time limits, the time taken hunting for keys while constructing open-ended responses and performance tasks might indirectly negatively impact student outcomes" (p. 8). In addition, students may not finish the test before the class is over. Frustration with limited keyboarding knowledge may decrease their tolerance for keyboarding tasks, causing them to stop prematurely (Poole & Preciado, 2016).

Regarding writing and composing, the current process and educational standards involve both handwriting and keyboarding skills (National Governors Association Center for Best Practices, 2010). Therefore, it is important for students to be successful with both skills (Feng, Lindner, Ji, & Joshi, 2019). Recent research supports explicit keyboarding instruction as critical for successful keyboarding skills and the overall writing process (Berninger, Abbott, Augsburger, & Garcia, 2009; Feng et al., 2019; Freeman, Mackinnon, & Miller, 2005). However, research is clear that keyboard instruction and use must not replace handwriting instruction during early years because of the different neurological processes required for keyboarding and handwriting and the importance of handwriting skill development as a foundation for other language and academic skill development (Feng et al., 2019; Kiefer et al., 2015; Mangen & Balsvik, 2016).

Keyboarding Instruction

Historically and initially, keyboarding was taught to students in late elementary grades or later through a formal process by certified business education teachers (Cantalupi, 1991). According to multiple studies from 1984 to 1988, middle to late elementary grades were an appropriate time to teach keyboarding skills (Pisha, 1993). One reason for later introduction was the belief that the hand size of students below third grade was too small for adequate dexterity (National Business Education Association, 1992).

Contrary to the thought that keyboarding should be instructed in late elementary grades, other research supports teaching keyboarding skills in early elementary grades (Berninger et al., 2009; Poole & Preciado, 2016; Rogers, Laehn, Lang, O'Leary, & Sommers, 2003). Earlier exposure to computers may impact the timing of instruction because keyboarding skills should be taught before computer skills are used. Keyboarding is the primary mechanism to interface with the computer for writing production

(Cantalupi, 1991). In the more recent past, keyboarding instruction has been introduced in grades kindergarten through second, focusing on early awareness of keyboarding skills (Rogers et al., 2003), while automatic letter production using a keyboard was faster than printing for elementary students in the second, fourth, and sixth grades (Berninger et al., 2009). Earlier instruction may also minimize the compensation technique of using a single finger, which is more difficult to alter once it becomes a habit. A recent study on teacher perceptions indicated that the first through the fourth grade may be the ideal time to teach touch keyboarding using all fingers on both hands (Poole & Preciado, 2016). Although the benefits of individual letter production are seen even at lower grades in these studies, it is important for explicit keyboarding instruction to be taught to assist in functional writing using a keyboard (Berninger et al., 2009).

Although the timing of keyboarding instruction has been discussed in the literature, there is limited literature on how the skills are taught (Niepert, 2018). Most of the research on keyboarding instruction identifies a single episode format of instruction where students complete anywhere from 15 to 40 min of instruction per day. The frequency ranges from once a week up to daily (Cantalupi, 1991; Freeman et al., 2005). The typical recommendation is for 25 to 30 hrs of total instruction, although intensity and duration of the keyboarding instruction are not consistent (Freeman et al., 2005). Up to 13 different keyboarding instructional programs used by teachers have been identified, yet none have been studied for efficacy (Poole & Preciado, 2016). A recent study found that for third grade students, computer-based instruction was more effective than traditional keyboarding instruction methods for both general and special education students (Niepert, 2018). Teachers were also found to perceive that keyboarding instruction did improve student performance on computer-based testing (Niepert, 2018; Poole & Preciado, 2016). However, no other recent instruction studies were located.

Keyboarding Skill Development

Keyboarding skills develop in a three-step motor skill progression (Stevenson & Just, 2014). Stage 1 uses cognition and vision while addressing letter identification and locating letters on the keyboard through touch keyboarding instruction. Stage 2 uses home keys and the development of muscle memory to select the keys using good technique. Stage 3 involves the mastery of the muscle memory and decreased use of vision to locate the keys. During Stage 3, speed increases and keyboarding becomes increasingly more automatic (Stevenson & Just, 2014). In addition to the motor learning process, Rao, Harrington, and Parsons (2000) showed that at least two distinct processes are noted neurologically in the brain during the acquisition of keyboarding skills.

The inability to progress effectively through these motor learning stages may result in poor keyboarding skills requiring additional cognitive resources and additional motor components (Barkaoui, 2014). Once keyboarding skills have become more automatic at the higher stages, students require less cognitive focus on the mechanics and are able to focus on the content of the task (Freeman et al., 2005). Therefore, initial instruction is important for developing keyboarding skill mastery, but ongoing practice is also recommended after establishing initial competency (Freeman et al., 2005). Despite its paramount importance, research on effective ways to teach keyboarding skills is scarce.

Keyboarding Speed and Technique

Keyboarding speed and accuracy are common measures of keyboarding skills. To be functional, keyboarding must be at least as fast as handwriting (Pisha, 1993; Stevenson & Just, 2014); however, the literature is conflicted about appropriate keyboarding rates for elementary students. Keyboarding speed is most commonly measured in words per minute (WPM). Specifically, gross WPM indicates the

number of words keyed per minute regardless of errors, whereas net WPM is the number of words keyed per minute with the errors removed; therefore, net WPM considers not only speed but also accuracy. Freeman, Mackinnon, and Miller (2005) completed a review of existing literature on keyboarding speed expectations and found variability in expectations where students in the fifth and sixth grades showed the largest variability from 4.7 to 70 WPM; students in the third and fourth grades ranged from 7.1 to 30 WPM; and students in the first and second grades ranged from 5 to 9 WPM. Speed achievements and expectations have ranged extensively, and limited consistency has been found throughout the literature (Freeman et al., 2005; Pisha, 1993).

Another keyboarding skill that can be measured is technique. Mastery of proper keyboarding technique allows students to key at a faster speed. Two primary keyboarding techniques identified in the literature are "hunt and peck" and "10 finger touch." Hunt and peck typically involves a single finger on one hand or a single finger on each hand and requires significant visual feedback to look at the keyboard. Hunt and peck is an inefficient technique that develops in the absence of keyboarding instruction (Pisha, 1993; Rogers et al., 2003). Those who use self-taught hunt and peck technique can type up to 35 WPM, but they plateau at this level because of the need for visual feedback. Use of hunt and peck limits the development of 10 finger touch and progress from a visually-driven technique to the kinesthetic-based one (Pisha, 1993). Ten finger touch keyboarding involves the mastery of the key position, use of the home row, and kinesthetic motor memory of each finger to keyboard without requiring visual feedback. Students trained to use the touch method of keyboarding can reach speeds at least double that of a proficient hunt and peck keyboardist (Pisha, 1993).

Because of the increasing need for effective keyboarding skills for students and the benefits that appropriate keyboarding technique offers, it is important to explore effective ways for students to learn these skills (Freeman et al., 2005). Little research exists on effective keyboarding instructional methods to inform occupational therapy practice. Using an experimental design with multiple groups to compare different keyboarding instructional methods is urgently needed. Keyboarding Without Tears® (KWT) was selected for use in this study because it provides a structured curriculum that is grade-based with a developmental approach and was developed by occupational therapists. This study examines the effectiveness of KWT as opposed to the standard approach for this district using free web-based activities. The purpose is to explore the effectiveness of a structured web-based keyboarding curriculum, KWT, in comparison to the standard district approach to teaching keyboarding skills for elementary students. The question posed in the study was: What is the effectiveness of KWT when compared to the standard district approach over one academic year for improving keyboarding speed and accuracy and keyboarding technique in typically developing kindergarten through fifth-grade students?

Method

A quasi-experimental design with nonequivalent groups was used to examine the effectiveness of two different keyboarding instructional approaches on improving keyboarding speed and accuracy and keyboarding technique assessed at pretest and posttest.

Participants

Students in two public lower elementary schools (kindergarten through second grade) and two public upper elementary schools (third through fifth grade) in the rural southern United States participated in this study. Two experimental schools (one lower and one upper elementary school) were selected first because of a researcher affiliation. The school district administration then recommended two control schools (one lower and one upper elementary school) because of their similarities to the

experimental schools in school structure, instructional methods, philosophy, and population. The county to which these four schools belong had a population of 105,114 with a median household income of $65,924 in 2016 (United States Census Bureau, n.d.). The students' ethnicity was collected but not reported because the data was not analyzed by this variable.

The inclusion criteria were: (a) students scheduled to attend weekly computer lab classes during the study academic year, (b) students whose parents did not choose to opt out of the study, and (c) students who completed both pretest and posttest. Students with disabilities were excluded from the study since they show different keyboarding performance compared to typically developing students (Berninger et al., 2009).

Procedure

The researchers obtained institutional review board approval for this study (UMCIRB 16-00531). After approval, one researcher completed a brief in-service for the experimental school computer lab teachers on the purpose of the study and curriculum training consisting of the philosophy and design of KWT, how to implement the program, and information available for teacher use in the educator dashboard associated with the program. The teachers at the control schools were informed about the purpose of the study and the role of their students and were asked to conduct their computer lab classes as usual.

According to the schools' recommendations, we determined parental permission using an opt-out method where students automatically participated in the study unless a parent chose to opt out. A letter explaining the study and the opt-out option from the study was sent home with all students, and no parents chose to opt out, rendering all of the students potentially eligible for the study. Pretests including primary outcome measures for experimental and control schools occurred during the computer lab times in August and September 2016 using desktop computers in respective schools. After pretests were completed in all schools, the students in the experimental schools started the KWT program, and students in the control schools started their usual computer lab activities during their weekly computer labs. A maximum of 27 weeks was possible for keyboarding instruction. Posttests were completed using primary outcome measures for all schools during the second week of May 2017. At this time, gender and ethnicity were obtained from official school records. Occupational therapy faculty members and occupational therapy graduate students who were trained and showed competency in all primary outcome measures conducted pretests and posttests. One of the researchers was available to all four schools for any questions they may have had during the study.

Keyboarding Instruction Method

In addition to computer lab time using windows-based desktop computers, the students at both lower schools had access to iPads in the classroom for learning activities. At both upper schools, the students had access to chrome books in the classrooms to be used for science, math, and language arts lessons and assignments. The students had access to the iPads and chrome books approximately two times per week. There were no differences in access to electronic devices at school between the experimental and control schools. Keyboarding instruction provided to the students was primarily through the electronic approaches described below. Class length did have slight differences between some grades and between some schools because the schools maintained their typical scheduling practices for all classes, including the computer lab classes.

Experimental group. We used KWT, developed based on the motor skill progression described in the literature review, in the experimental schools (Stevenson & Just, 2014). For Stage 1, pre-

keyboarding exercises were a focus of levels kindergarten through the second grade. The students were introduced to mouse skills, key identification and position, and beginning to integrate the two hands in preparation for touch keyboarding. Every grade level began with an optional pre-keyboarding section to teach the students these skills if they were new to keyboarding. During Stage 2, the KWT activities became more complex to refine skills with grade appropriate activities. Although Stage 2 activities were introduced in kindergarten, the number of activities at this level increased with each grade level. Repetition of common motor patterns was embedded in a game-like format to help increase necessary muscle memory for effective touch keyboarding. The students progressed to keyboarding in Stage 3 as they advanced in grade and toward the end of the upper grade activities where the tasks become more automatic and integrated required finger movements. In the application for the third through the fifth grade, pre-keyboarding skills were reviewed, but the primary focus was developing speed and accuracy through the touch keyboarding technique using a full keyboard. The skills required for computer-based testing were also addressed in these upper grades (Olsen & Knapton, 2016).

Cross-curricular content, such as language arts, science, art, Greek and Latin, and famous people, were included in all grade-level applications for kindergarten through the fifth grade to make the keyboarding activities meaningful and purposeful to the students. The students were encouraged to earn digital badges and medals by completing activities. Teacher-led lessons focusing on digital literacy and digital citizenship were not included in this study to reduce the variability among the teachers. Each grade-specific program was designed for 36-week implementation over the school year and included 409-578 keyboarding activities, depending on the grade level.

All of the students used their appropriate grade level KWT program through this web-based student-directed application designed with an appropriate number and complexity of activities and an appropriate developmental progression. The application included written and auditory prompts as well as video demonstrations. Each student was assigned an annual license for access to the appropriate grade-level application with an independent login.

Although the implementation of KWT is flexible and can be completed daily for 5-10 min or weekly for 30 min, the students in the experimental schools had access to the application only during the weekly computer labs for approximately 30 min of the class session (Olsen & Knapton, 2016). The computer lab class durations ranged from 45 to 60 min for the lower school and 45 min for the upper school. To monitor student progress in the use of the KWT program, the researchers tracked the overall progress of the students in the experimental schools using the online educator dashboard provided by KWT.

Control group. The students using the district standard approach completed pre-keyboarding and keyboarding-related activities and training maintaining their typical instructional approach. The lower school, grades kindergarten through second, used FreeTypingGame.Net (FreeTypingGame.net, LLC, 2018) for keyboarding instruction. This web-based program did not have a login feature and did not track the students' progress. It was not a formal curriculum, but rather a website that offered free keyboarding games, free keyboarding lessons, and free keyboarding tests. All free keyboarding games offered the same 40 options and were structured the same way, where students key the combination of letters on the screen before the time runs out to earn points. In addition to the games, there were 30 keyboarding lessons that were traditional, repetitive practice of two key combinations that did not integrate with other letters. The keyboarding lessons could be used as a teaching lesson and later paired with a game incorporating the keys emphasized in the lesson. There were 10 different game choices to

pair with the lessons. The lessons could also be customized by the teacher to focus on specific keys. In addition, there were 40 different typing tests to choose from, each lasting 1 to 5 min. The students in the lower school also played interactive games online (PBS Kids, 2017) that involved mouse skills and the use of the keyboard as game controls. The kindergarten and first-grade activities focused on mouse functions, and the second-grade activities focused on beginning keyboarding skills with key identification. FreeTypingGame.Net tests were used with the students periodically throughout the year. These tests were used more frequently with second-grade students.

The students in the third through fifth grades used Beginner Typing online keyboarding lessons from Learn Typing© (Holding, 2007). This approach was not game-based or differentiated by user grade level. In fact, the program was not specifically designed for children but was created for individuals of all ages who want to learn keyboarding. Learn Typing© had a beginner and advanced level with seven lessons each. There were seven additional lessons available on keyboarding shortcuts. The beginner lessons started with the home row keys on each hand and then began to integrate additional letters and use of both hands together. The lessons were read by the students and then followed by traditional repetitive keyboarding practice. These lessons did not provide feedback on correctness of activities or user speed and accuracy. Learn Typing© had an embedded keyboarding game that just used individual letters or letter combinations. Keyboarding tests were also available that showed students' gross WPM but did not clearly indicate accuracy. The students were also introduced to computer use skills, such as word processing and keyboarding technique. Keyboarding speed and accuracy was assessed through an online speed test measuring WPM and accuracy. The computer lab class durations for the lower school were 35 min and for the upper school they were 45 min. Minutes spent specifically on keyboarding instruction were not measured.

Instruments

Outcome measures assessing keyboarding speed and accuracy and keyboarding technique included Typing Test Pro© and a keyboarding technique observation that were completed at pretest and posttest. Since technique has a relationship to speed and accuracy that is not well documented, both were measured to get a more accurate understanding of student performance (Pisha, 1993). Data was collected during the students' regularly scheduled computer classes.

Typing Test Pro©. Typing Test Pro© measured keyboarding speed and accuracy and was completed through an online website (TypingMaster, Inc., 2016). All students completed a 1-min warm-up speed and accuracy check to be familiar with task demands, immediately followed by a 1-min speed and accuracy test. The tasks required copying a first-grade reading level passage that appeared on the screen in paragraph form. Editing functions were disabled so that the students could not backspace to erase incorrect letters. Three calculations from the 1-min test were produced by Typing Test Pro: (a) gross WPM, which is the words per min not adjusted for errors in keyboarding; (b) accuracy in percentage, which is the number of correct characters divided by the total characters; and (c) the net WPM, which is the gross WPM minus the errors. The net WPM was used in data analysis for this study. Net WPM is a consistent measure found in the literature and was the recommended score for use in research (Barkaoui, 2014). Test-retest reliability of Typing Test Pro© was reported as very high (r = .94) when comparing net WPM of 97 college students who completed two keyboarding samples (Barkaoui, 2014).

Keyboarding technique observation. Keyboarding technique observation was completed by the researchers while the students completed the Typing Test Pro© tests. This observation was determined

using a 5-point ordinal scale. The 5-point scale ratings included: 1 = one finger on one hand and repeatedly using visual feedback; 2 = both hands, one finger each, while repeatedly using visual feedback; 3 = two to four fingers on both hands and repeatedly using visual feedback; 4 = all fingers on both hands and repeatedly using visual feedback; and 5 = all fingers on both hands while looking at the monitor relying on kinesthetic feedback. Level 5 is the most skillful and proficient keyboarding technique (Weigelt Marom & Weintraub, 2010). This observation rating appears to align with the motor learning progression where Ratings 1-2 would align with Stage 1, Rating 3 may align with Stage 2, and Ratings 4 and 5 may align with Stage 3 (Stevenson & Just, 2014). This observation rating was completed by three researchers at pretest and posttest and one additional researcher at posttest.

Data Analysis

We used IBM SPSS Statistics (Version 24; IBM Corp., Armonk, NY) for all data analyses. Prior to pretest and posttest, inter-rater reliabilities for keyboarding technique ratings among the three and four raters, respectively, were checked using a two-way mixed, absolute, average-measures intra-class correlation coefficient (ICC) according to Hallgren (2012). The raters individually watched 10 sample videos of keyboarding and rated the keyboard technique of all samples. Two-way mixed, over two-way random, was used because the pool of raters included in the testing of inter-rater reliabilities is the same as the pool of raters who rated keyboarding techniques in the study. Absolute, over consistency, was used because absolute agreements, instead of consistent patterns of rating, among the raters were considered more important for keyboarding technique ratings. Lastly, an average-measures ICC, over a single-measures ICC, was used because three and four raters rated all 10 sample videos and the ratings by those multiple raters were used to test research questions (Hallgren, 2012). We selected this method over collecting data during the actual keyboarding technique observation for calculating inter-rater reliabilities because of the limited number of trained raters available during the actual observations. An ICC value below .40 is considered poor agreement, a value between .40 and .59 is fair agreement, a value between .60 and .74 is good agreement, and a value between .75 and 1.0 is excellent agreement (Hallgren, 2012). Descriptive statistics were used to document the gender of the students in all schools.

To examine the research questions on keyboarding speed and accuracy, we used mixed analysis of variance (ANOVA) with an alpha value of .05 after confirming the assumptions. When we found significant changes between pretest and posttest in net WPM and technique from the mixed ANOVA, we performed post-hoc tests using Wilcoxon signed-rank tests with Bonferroni correction alpha value of .025 to examine the changes in each intervention school per grade because of the assumption violation of normal data distribution. Pre and posttest net WPM data was not normally distributed except for the posttest of the net WPM for the fifth grade in the control group ($p = .20$). Because of the nature of the keyboarding technique ratings (ordinal scale) we used Wilcoxon signed-rank tests for within-group comparisons and Mann-Whitney tests for between-group comparisons with an alpha level of .05.

In addition to the main analyses, we compared the changes in net WPM and keyboarding technique between the lower (kindergarten through second) and the upper (third through fifth) schools using Mann-Whitney tests because of the assumption violation of normal data distribution or the nature of the ratings (ordinal scale). Non-parametric tests were used because keyboarding technique data were not normally distributed.

In addition to testing the statistical significance, effect sizes (r) were calculated to document the degrees of changes or differences in net WPM and keyboarding technique. Effect size r values between 0 and 0.09 indicate negligible effect, values between 0.10 and 0.23 indicate small effect, values between

0.24 and 0.36 indicate medium effect, values between 0.37 and 0.70 indicate large effect, and values 0.71 or greater indicate very large effect (Tickle-Degnen, 2001).

Results

Seven hundred and eighty-six students (386 males and 399 females) in the experimental schools and 953 students (482 males and 471 females) in the control schools participated in the study (see Table 1). The students in all four schools, except for those in kindergarten, had attended computer lab sessions with the district standard approach in previous academic year(s), if they attended one of these schools. Inter-rater reliabilities for keyboarding technique ratings among three and four raters were both excellent (ICC = 0.96 and 0.97, respectively), indicating that raters had a high degree of agreement and suggesting that keyboarding technique was rated similarly among raters.

Table 1
Participant Gender

		Gender n (%)	
Grade	School	Male	Female
Kindergarten	Experimental	54 (46.6)	62 (53.4)
	Control	77 (51.0)	74 (49.0)
First	Experimental	53 (46.5)	61 (53.5)
	Control	82 (57.7)	60 (42.2)
Second	Experimental	68 (55.7)	54 (44.3)
	Control	76 (46.9)	89 (53.9)
Third	Experimental	58 (43.6)	75 (56.4)
	Control	86 (52.8)	77 (47.2)
Fourth	Experimental	78 (53.8)	67 (46.2)
	Control	94 (52.2)	86 (47.8)
Fifth	Experimental	76 (48.7)	80 (51.3)
	Control	67 (44.1)	85 (55.9)

Keyboarding Speed and Accuracy

We found significant improvements in net WPM in all grades at posttest compared to pretest ($p < .001$). Specifically, we found significant improvements ($p < .001$) in net WPM in the experimental group for all grades with large to very large effect sizes ($r = 0.60 – 0.75$) and significant improvements ($p < .001$) in net WPM in the control group for all grades with large effect sizes ($r = 0.39 – 0.61$) according to the post hoc tests. All effect sizes for the experimental group were higher than the highest effect size of the control group except for one. There were significant differences in net WPM changes between the experimental and control groups, favoring the experimental, in all grades, except for kindergarten, with small to medium effect sizes ($r = 0.11 – 0.28$). We found significant interaction effects in net WPM between time and schools in all grades, except for the second grade (see Table 2). Lastly, in both approaches, the students in the upper schools showed significantly greater improvements in net WPM than those in the lower schools ($p < .001$; $r = 0.47$ and 0.29, respectively) (see Table 3).

Keyboarding Technique

We found significant improvements in the keyboarding technique in all grades in posttest compared to pretest, except for the kindergarten control students. Specifically, we found significant improvements in the keyboarding technique for all grades in the experimental group with medium, large, or very large effect sizes ($r = 0.25 – 0.81$). In addition, we found significant improvements in the control

group keyboarding technique of all grades, except for kindergarten, with negligible, medium, large, or very large effect sizes (r = 0.05 – 0.80; see Table 4).

Table 2

Results of Change in Net Words Per Minute Between Times and Among Schools

				F and *p*			Effect Size *r*	
Grade	School	Pre *M* (*SD*)	Post *M* (*SD*)	Time	School	Interaction	Pre-Post	Between Schools
Kindergarten	Experimental (n = 116)	0.03 (0.16)	0.41 (0.49)	85.52 p < .001	0.00 p = .99	3.96 p = .048	0.60*	0.13
	Control (n = 151)	0.09 (.29)	0.34 (.53)				0.39*	
First	Experimental (n = 114)	0.59 (0.82)	1.94 (1.84)	110.44 p <.001	5.19 p = .023	19.65 p <.001	0.65*	0.26
	Control (n = 142)	0.67 (1.01)	1.22 (1.44)				0.42*	
Second	Experimental (n = 122)	2.06 (1.80)	4.00 (3.03)	150.02 p <.001	8.12 p = .005	2.76 p =.10	0.66*	0.11
	Control (n = 165)	1.57 (1.89)	3.05 (2.75)				0.61*	
Third	Experimental (n = 133)	3.85 (3.25)	7.79 (4.34)	201.80 p <.001	13.48 p <.001	16.96 p <.001	0.75*	0.25
	Control (n = 160)	3.30 (3.02)	5.47 (4.40)				0.54*	
Fourth	Experimental (n = 142)	7.32 (4.29)	12.18 (5.99)	185.41 p <.001	33.50 p <.001	17.23 p <.001	0.72*	0.28
	Control (n = 175)	5.85 (3.79)	8.43 (4.52)				0.53*	
Fifth	Experimental (n = 155)	11.12 (5.63)	16.11 (6.54)	180.74 p <.001	32.88 p <.001	11.19 p =.001	0.69*	0.19
	Control (n = 149)	8.79 (4.70)	11.79 (5.66)				0.55*	

*p < .001.

Table 3

Comparison of Changes in Net Words Per Minute and Keyboarding Technique Between Lower and Upper Schools

	Change in net words per minute (Post-Pre)			Change in keyboarding technique (Post-Pre)			
	n	*M* (*SD*)		*n*	*M* (*SD*)	*Mdn*	
Experimental							
Kindergarten through second	352	1.24 (1.92)	z = -13.207 p < .001	351	1.25 (1.02)	1.00	z = -8.213 p < .001
Third through fifth	430	4.62 (5.04)	r = 0.47	430	0.61 (0.97)	1.00	r = 0.29
Control							
Kindergarten through second	458	0.78 (1.59)	z = -8.811 p < .001	456	0.13 (0.53)	0.00	z = -16.264 p < .001
Third through fifth	484	2.58 (4.23)	r = 0.29	491	1.00 (0.89)	1.00	r = 0.53

Table 4

Results of Change in Keyboarding Technique Between Times and Among Schools

Grade	Schools	Pre *Mdn*	Post *Mdn*	*z* and *p* Pre-Post	*z* and *p* Between Schools	Effect Size *r* Pre-Post	Effect Size *r* Between Schools
Kindergarten	Experimental (n = 116)	1.00	2.00	-6.935, $p < .001$	-9.056, $p < .001$	0.64	0.56
	Control (n = 149)	1.00	1.00	-0.577, $p = .564$		0.05	
First	Experimental (n = 114)	1.00	2.00	-8.107, $p < .001$	-8.617, $p < .001$	0.76	0.54
	Control (n = 142)	1.00	1.00	-3.983, $p < .001$		0.33	
Second	Experimental (n = 121)	1.00	3.00	-8.886, $p < .001$	-11.075, $p < .001$	0.81	0.65
	Control (n = 165)	1.00	2.00	-3.442, $p = .001$		0.27	
Third	Experimental (n = 133)	2.00	3.00	-7.665, $p < .001$	-3.903, $p < .001$	0.66	-0.23
	Control (n = 161)	1.00	3.00	-10.167, $p < .001$		0.80	
Fourth	Experimental (n = 142)	2.00	3.00	-7.662, $p < .001$	-3.008, $p = .003$	0.64	-0.17
	Control (n = 179)	2.00	3.00	-10.346, $p < .001$		0.77	
Fifth	Experimental (n = 155)	3.00	3.00	-3.133, $p = .002$	-3.918, $p < .001$	0.25	-0.22
	Control (n = 151)	3.00	3.00	-7.310, $p < .001$		0.59	

There were significant differences in changes in the keyboarding technique between the approaches in all grades ($p < .001$ for all grades, except for fourth grade $p = .003$) with large effect sizes favoring the experimental group for kindergarten to the second grade and small effect sizes favoring the control group for the third to fifth grades (see Table 4). Lastly, the students in the experimental lower school showed significantly greater improvements in keyboarding technique than those in the experimental upper school ($p < .001$, $r = 0.29$), whereas the students in the control upper school showed significantly greater improvements in keyboarding technique than those in the control lower school ($p < .001$, $r = 0.53$) (see Table 3).

Discussion

Keyboarding instruction, regardless of approach, demonstrated an increased speed, accuracy, and technique among elementary students. Because there are many factors influencing the keyboarding skills of students, it is important to recognize factors that could have impacted results overall that are difficult to measure. These factors could have impacted any class in either group and include differences in teaching styles, teacher attitude toward importance of keyboarding instruction, the amount of time spent in computer class, computer use at home, student demographic differences, the number of days computer classes were cancelled because of the other school functions, and computer and technology glitches.

Keyboarding Speed and Accuracy

KWT claims to improve keyboarding speed and accuracy because the developmental progression of skills based on the motor learning stages and engaging game-based activities are integrated throughout each grade level application (Learning Without Tears, 2017; Stevenson & Just, 2014). The motor learning Stages 2 and 3 are closely linked to keyboarding speed and accuracy. Since these stages are most prevalent in the upper grade applications of KWT, the largest changes from pre to posttest occurred in the experimental upper school and seemed to reflect the intention of the curriculum. In addition, the control approach also showed a similar pattern of improvement to the experimental approach, but to a lesser degree, indicating older students have more potential to improve their keyboarding speed and accuracy than younger students during the given period.

When looking at the differences between the experimental and control approach, we identified additional potential reasons for our findings. First, student-produced keyboarding responses in KWT are meaningful to the student as opposed to rote practice. For example, the letter keyed may complete a puzzle, or the words keyed may describe a famous person. This meaningful approach aligns with the occupational therapy expertise of many who contributed to the program's development. Stevenson and Just (2014) asserted the importance of using meaningful practice in motor learning of and fluency in keyboarding. In addition, KWT includes speed and accuracy checks that provide feedback to students on their progress throughout each grade level application. Through this feedback system the students may have had a better understanding of their status in the program, thus encouraging them to improve their performance. Feedback is an important component of the motor learning theory that guided the development of KWT. Feedback has been found to enhance self-efficacy and intrinsic motivation when learning a motor task (Abbas & North, 2018; Stevenson & Just, 2014). On the contrary, the control approach included primarily keyboarding games that were repetitive with less meaning and may not have provided structured feedback to students.

Changes in WPM for the younger grades may reflect the developmental skills of these students as well as the focus of the instruction. The KWT program for the lower grades focuses more on pre-keyboarding skills, including mouse skills and letter recognition with beginning integration of both hands in kindergarten, and this is considered developmentally appropriate (Rogers et al., 2003). Recognizing all print capital and lowercase letters is standard for kindergarten students to learn; therefore, using an outcome measure requiring mastery of capital and lowercase letters for kindergarten students may not accurately reflect their keyboarding skills (National Governors Association Center for Best Practices, 2010). In addition, the keyboard on standard desktop computers as used in this study display capital versions of the letters while the written passages on the keyboarding assessment are primarily lowercase letters. Kindergarten students are still learning to recognize capital and lowercase letters, thus requiring extra time to process the alphabet knowledge, which negatively affects keyboarding speed and accuracy. Locating the keys individually slows down keyboarding speed (Poole & Preciado, 2016). As the student progresses into the first and second grade, more keyboarding specific skills are added, while the pre-keyboarding and mouse skills are decreased. The teachers believe that the first grade may be a good time to begin keyboarding skills (Poole & Preciado, 2016). Thus, WPM may not be a good measure for kindergarten skills. In the control group, the techniques did have a larger focus on traditional keyboarding skills, but the students may not be developmentally ready for this approach, as identified in earlier literature (Pisha, 1993; Rogers et al., 2003).

Keyboarding Technique

Possible reasons for the improvements in the keyboarding technique for the experimental group include some unique features of KWT. This program uses horizontal color-coded rows for a kinesthetic instructional approach, which includes a specific order in which keys are taught so that students can systematically learn the locations of different keys using proper keyboarding technique (Learning Without Tears, 2017). In addition, KWT appears to be more consistent throughout the entire program and well-structured in terms of grade-level appropriate activities for keyboarding technique reinforcement. The potential effects of consistency and structure were observed through the lower variances among the effect sizes of improvements in the keyboarding technique in the experimental schools compared to those in the control schools. The control group did not have a singular formal curriculum because the teachers selected activities to meet the school and district needs. However, the students did spend time weekly on computer-based activities, which lend themselves to improving skills over the course of the school year.

The differences in keyboarding technique findings may be explained by the different focuses that KWT places on the different grades, the students' first exposure to KWT, types of keyboarding technique activities provided to each grade, and teachers' different emphasis on keyboarding technique instruction. First, KWT for kindergarten through the second grade focuses more on identifying letters on the keyboard and finger placement, whereas the third through fifth grades focus more on speed and accuracy with only a brief review of finger placement and technique (Olsen & Knapton, 2016). We chose to disable the option of skipping this review section for finger placement and technique because we did not have any information on the students' keyboarding technique levels prior to the pretest. Therefore, it is logical that the greatest improvements in keyboarding technique would appear in kindergarten through the second grade while more improvements in speed would be seen in the third through fifth grades. In addition, since all of the students in the experimental group were using KWT for the first time and the third- through fifth-grade students only briefly reviewed finger placement and technique, it is also logical for the third- through fifth-grade students to show smaller improvements in keyboarding technique compared to the kindergarten through second-grade students in the experimental group. Because the lower grade KWT applications have the largest focus on motor learning Stage 1, locating the keys and keyboarding technique, the largest differences in improvement in technique between the experimental lower school and the control lower school are logical. We may have observed larger improvements in the keyboarding technique of the third- through fifth-grade students if they had started using KWT in kindergarten through the second grade and then continued improving their keyboarding technique on those foundational skills. This recommendation is supported by teacher perceptions regarding the importance of keyboarding instruction to develop efficient keyboarding skills. However, teachers have also indicated that, with the introduction of Common Core State Standards, core classes, such as math, have become the focus on instruction time over the foundational skills, such as keyboarding. It is ironic that teachers believe overall performance on computer-based testing in schools would drop drastically without the keyboarding skill foundation (Poole & Preciado, 2016).

However, we may have observed even smaller improvements in the keyboarding technique of the third- through fifth-grade students if they skipped the review section for finger placement and technique. Furthermore, the types of keyboarding technique activities used in KWT may be age-appropriate more for kindergarten through the second grade than the third through fifth grades. These activities included matching individual pictures with the correct letter key that may have been perceived

as “too childish” to third through fifth grade students. Therefore, development of more engaging activities for third- through fifth-grade students that enforce the use of two hands may be beneficial for these students without prior formal keyboarding instruction to develop a higher level of keyboarding technique. Lastly, the teachers’ different emphasis on keyboarding technique instructions may have affected the results. The teachers in the experimental lower school and the control upper school verbally reported that they used strategies reinforcing keyboarding technique (the two groups with the largest improvements), although no information on the details of their strategies was collected. Researching teacher reinforcement techniques would be a logical next step in understanding the effects of different keyboarding instruction approaches.

Limitations

Although this study includes a large sample, it is important to recognize the limitations that impact the interpretation of the results. We did not randomize because we wanted to conduct the study in the natural educational environment and to increase the number of participants, considering the scarcity of evidence on this topic. Randomization in each school would have introduced bias because all computer classes in each school were taught by the same teacher. Therefore, having a teacher implementing both approaches at the same time would have introduced bias. Variability in the teaching styles and lesson plans among the teachers and variability in computer lab durations between the grades and schools may have affected the study results. In addition, attendance records for computer labs were not available but may have affected the results. However, attendance alone does not equate to time spent on keyboarding activities. Although class durations differed, the teachers’ report indicated that all students spent similar amounts of time on keyboarding instruction. However, there was no specific way to measure for this effectively. Even if time spent at the computer with keyboarding applications open was measured, it would not be possible to track the amount of time the students attended to these specific tasks. Furthermore, although this potential variability and lack of information on specific keyboarding activity durations and attendance are still a limitation of our study, it, in fact, shows the positive aspect of the experimental keyboarding curriculum. Compared to the control approach, where the tracking of the attendance and compliance to the planned progress are difficult, the experimental approach provides the data on student progress.

Conclusion

Limited research on keyboarding has been conducted, especially in recent years. This study is the first of its kind to explore how keyboarding instructional methods impact the development of keyboarding speed and accuracy and keyboarding technique in elementary grades. The effectiveness of KWT in improving keyboarding speed, accuracy, and technique compared to the district standard approach is supported for typically developing kindergarten through fifth-grade students.

Based on the findings of this study, professionals involved in assisting with keyboarding skill development in children are recommended to begin training in these skills in early elementary grades, especially to assist in proper keyboarding technique development. While using free web-based activities are beneficial to improving keyboarding speed and accuracy, as well as keyboarding technique, using a developmentally-based curriculum, such as KWT, may further enhance improvements in the keyboarding skills of elementary students.

Further studies are needed to determine the effectiveness of different keyboarding instruction approaches for students with special needs, the effects of different durations of keyboarding instruction approaches, appropriate keyboarding skill expectations for different grade levels, the relationship

between keyboarding speed and keyboarding technique, and the cumulative effects of having keyboarding instruction training in successive years.

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