Abstract Title Page

Title: Teaching Early Knowledge of Whole Number Concepts Through Technology: Findings from a Feasibility Study of an iPad Delivered Kindergarten Mathematics Intervention

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Abstract Body

Background / Context:

Children enter kindergarten with variable levels of mathematics skill and knowledge gained from informal learning opportunities at home, preschool, and daycare. Many perform well once they receive formal mathematics instruction. However, if students do not develop an initial understanding of the most basic aspects of formal mathematics, they are likely to have difficulty understanding or succeeding at mathematics they will encounter in first grade and beyond. This puts these students at an academic disadvantage that is likely to become exacerbated over time. In fact, longitudinal studies of mathematics achievement have suggested that kindergarten mathematics concepts are pivotal foundational skills for future mathematics performance (Duncan, et al., 2007; Morgan et al., 2009). Accordingly, there has been a targeted effort to create effective early mathematics interventions that support the development of whole number understanding through robust number sense curricula (Clarke, et al., 2011; Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012).

Early mathematics interventions are often intended for use in Response to Intervention (RtI) systems to support the mathematics achievement of students at all levels (Fuchs, Fuchs, & Compton, 2012; Fuchs, Fuchs, & Hollenbeck, 2007) and to prevent students from developing mathematics learning difficulties. As RtI approaches gain traction, there has been particular interest in the development of Tier 2 interventions that provide intensive instruction to students above and beyond their core mathematics instruction. However schools encounter barriers related to resources and time requirements for screening students, implementing interventions, and progress monitoring in RtI systems.

Technology-based interventions are a potentially promising means of surmounting those barriers. This is particularly true if the interventions customize instruction to meet individual students' needs in a way not feasible in a classroom or resource-strapped context. In fact, technology holds great promise as an answer to the intervention implementation dilemma. Devices, software, and apps are often quite affordable and compatible with classroom contexts. However, questions remain as to whether or not educational technology can be considered a reliable means for improving student outcomes (Kebritchi et al., 2010; Slavin & Lake, 2008; Collins & Halverson, 2009; Polson & Morgan, 2010; Young, et al., 2012).

In an effort to merge the promise of educational technology with the need for early mathematics interventions that can be utilized in RtI systems, the study reported here details findings from the development and feasibility trials of a kindergarten iPad-based whole number intervention. The efforts reported here detail attempts to develop an effective kindergarten mathematics curriculum delivered on a hand-held tablet. Adherence to research-based curriculum development procedures (Clement, 2007), the utilization of guidelines for effective instructional design (Baker, et al., 2002; Gersten et al., 2009; Rosenshine, 2012), and attending to findings related to the effects of educational technology on academic performance to guide decision-making (Hattie, 2009; Kulik & Kulik, 1991; Roblyer, Castine, & King, 1988) all informed the development of the intervention reported here.

Purpose / Objective / Research Question / Focus of Study:

The primary research question for this study was how successful was the classroom implementation of the KinderTEK mathematics intervention during the project's Feasibility Testing phase? Follow up questions included:

1. What was the relation between the use of an iPad-based mathematics intervention based on effective instructional principles and mathematics performance for kindergarten students?
2. What was the nature of the relationship between usage variables and mathematics screening measures for all students?
3. To what extent was student satisfaction with the KinderTEK iPad app related to usage and mathematics ability?
4. To what extent were teachers satisfied with the KinderTEK intervention system?

Setting:

The KinderTEK feasibility study was conducted winter/spring of 2013 in a moderate sized school district in the Pacific Northwest. Approximately 20% of the district's students were Hispanic or Latino and approximately 17% received special education services. Within the three participating schools, 7–27% of students were reported to be English language learners and free–reduced lunch eligibility ranged from 43–78% (NCES, 2013). All of the participating schools were Title 1 eligible and total school populations ranged from 420–530. KinderTEK was implemented in 10 classes; a mix of morning and afternoon classes taught by six teachers, two at each school.

Participants:

To examine the feasibility of the KinderTEK intervention for use in a tiered intervention system, participants for this study were a convenience sample comprised of six teachers (one male) with varying levels of technical expertise, and their kindergarten students. Given the primary development goal of supporting the learning of at-risk kindergarten students, five at-risk students from each class were identified as target students for the feasibility study. The target students were selected based on teacher recommendation, evidence of regular attendance, and screening data collected from student performance on a brief battery of number sense curriculum based measurements (Clarke et al., 2012). These 50 students were the primary focus of our research efforts (See Appendix B, Table 1 for complete target student demographic information). However, because KinderTEK has the potential to accommodate a range of learners and teachers expressed interest in introducing this technology to all their students, all students were invited to participate in the study. This increased our user-base from 50 to 213.

Intervention:

KinderTEK is a system of iPad applications ("apps"; Appendix B, Figure 1) providing mathematics intervention to struggling kindergarten students. Comprised of one app used individually by students and another app that allows teachers to monitor student use and progress in real-time, KinderTEK targets whole-number content outlined in the Common Core standards (CCSSO, 2010) and provides explicit instruction appropriate to each student's learning needs. The intervention utilizes personalized instruction, scaffolding, feedback, and help; provides deliberate practice to build fluency; relies on embedded assessment; and includes teacher-customization, monitoring, and reporting features. KinderTEK incorporates key instructional design principles found to be especially effective for struggling students (Gersten et al., 2009), and key educational technology design principles (Mayer & Moreno, 2003) to provide quality instruction to students using iPads independently, customizing the learning experience for each student.

Although the KinderTEK intervention has the capability to allow student choice from a range of appropriate activities, progress through the curriculum was constrained in this study and all students completed the same activities in the same order. Time spent on each activity varied,

however based on student accuracy and mastery of the learning objectives. Teachers were asked to support target students' use of the KinderTEK intervention individually for 15 minutes per day, 3 days per week in addition to regular, whole class mathematics instruction. At teachers' discretion and convenience, other consented students also used KinderTEK.

Research Design:

A mixed methods design was utilized to evaluate the feasibility and utility of the KinderTEK iPad mathematics intervention in authentic settings. The study reported here constituted the Feasibility Testing phase of an iterative cycle of technology-based intervention development. The primary study concerns were whether KinderTEK functioned as intended, whether participants enjoyed using KinderTEK, whether it could be feasibly integrated into the school day, and whether the data logged by the apps was accurate. For this reason, no control group was included.

All student use and performance data was logged and available for analysis. Total duration of use was captured by log data. Because app use varied dramatically across the 213 users, progress through the intervention and total time of use were used to classify both target and non-target students into sub groups for analyses.

Data Collection and Analysis:

Information presented here includes both qualitative and quantitative data: (a) student outcomes as evidenced by embedded progress monitoring data and pre/post test gains, (b) informal classroom observations, (c) student and teacher feedback provided through surveys and interviews, and (d) automatically technologically tracked KinderTEK usage data

Student Outcomes. Student performance was monitored and logged on a daily basis to support the continued refinement of the intervention throughout the feasibility study. As a result, there is comprehensive data about individual student exposure and performance within KinderTEK. Key summary information (e.g., number of activities attempted and completed, number of attempts to mastery, dosage) will be presented for both target and non-target students.

As noted earlier, the 50 at-risk target students were the main focus of this study. The at-risk target students completed (a) a 0-20 number line task adapted from a 0-100 number line procedure (Booth & Siegler, 2008), (b) the recently published Number Sense Screener (Jordan et al., 2012), (c) a collection of early mathematics curriculum based measures entitled Assessing Student Proficiency in Early Number Sense (ASPENS, Clarke, et al., 2012), and (d) an additional oral counting Early Numeracy-Curriculum Based Measure (Chard et al., 2005).

Surveys and Exit Interviews. Data collectors asked students questions about their KinderTEK experience (e.g., likes, dislikes, frustrations; favorite activities; suggestions for improvement) and recorded their responses. Teachers completed an online survey with similar, but far more detailed questions including their own technology expertise, their use of technology in the classroom, and impressions of their students' experiences with the intervention.

Analyses. Quantitative analyses included univariate descriptive procedures and regression techniques to evaluate the relationship between intervention use, academic variables and satisfaction with KinderTEK. Qualitative analyses drew on data from teacher reports, exit interviews with teachers and target students, and observations of the app in use by target students.

Findings / Results:

Regression analyses conducted using usage variables (i.e. total time, activities completed, number of practice opportunities; Appendix B, Table 2) to predict target students' (n = 50) gain scores on mathematics measures suggested that there was some evidence of a statistically

significant association between KinderTEK use and changes in mathematics performance in this brief feasibility study. Student gains in oral counting were positively related to minutes of use and the number of activities completed, $b = .073$, $t = 2.015$, $p = .052$, and $b = 5.786$, $t = 2.211$, $p < .05$, respectively. Student gains on other CBM measures and pre- and post-test differences on summative measures were not conclusively associated with KTEK usage variables (Appendix B, Table 3).

Comparative analyses conducted with the full sample (n = 213) suggested that pre-test ability was related to student performance within the intervention, where students with higher pre-test ASPENS composite scores took less time per activity, $b = -.180$, $t = -7.859$, $p < .001$, and got a higher proportion of practice opportunities correct, $b = .001$, $t = 7.023$, $p < .001$. However, there was no clear statistical evidence that total progress through the KinderTEK intervention was related to overall post-test mathematics scores.

Teacher and student satisfaction with the KinderTEK student app drawn from interviews and survey response data indicated that the majority of students and teachers were satisfied with KinderTEK (Appendix B, Table 4). Students were generally satisfied with KinderTEK and levels of satisfaction were not statistically related to academic performance or usage variables. Teachers were least satisfied with the pacing of the content and most suggested revising the intervention to allow students to respond to prompts without listening to the full directions, and reducing the amount of verbal instructions. Teachers were moderately satisfied with the interface, intuitiveness, and responsiveness of the app, and were satisfied with the functionality of the KinderTEK teacher app (i.e., system interface and progress monitoring capabilities).

Conclusions:

Studies that seek to determine the overall impact and effectiveness of an individualized, technologically delivered kindergarten mathematics intervention face significant challenges. Two of these considerations are of particular relevance to the synthesis of results from this feasibility study, which will be used to guide revising the intervention, and planning a pilot study focused on student outcomes: (1) Because each child moves through the curriculum at his own pace, there are challenges in grouping students into conditions and comparing mathematics performance. At-risk students' intervention experiences vary greatly, thus a consideration of dosage (i.e., duration of use or progress through the app) may be a necessary covariate in analyses. (2) Although iPad-delivered interventions have many useful stand-alone, technology-enhanced capabilities, challenges related to technology-based implementation demands persist and affect teacher and student experiences when using the intervention. Separating teacher and student feedback about the intervention into conceptual features of KinderTEK and general feedback about the delivery method is an essential and complicated task. Careful survey design, thoughtful interview questions and clear observation protocols are all valuable tools in this endeavor and careful analysis of qualitative data will be essential, as well. Future research is recommended to evaluate the relationships between teacher feedback and technological comfort and experience to inform technology-based intervention implementation.

In spite of the challenges, these results are important to the iterative process of curriculum development. Lessons learned throughout usability trials and the feasibility study reported here become valuable tools for the continued adaptation and refinement of the KinderTEK intervention in preparation for larger scale pilot study investigations. Technology-based interventions have great promise, but require thoughtful design, development, and continued adjustment for maximal effectiveness with kindergarten students in authentic contexts.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Table 1. Participants Demographics

		Target Sample
Child Characteristics		
Child Age M (SD)		6.23 (0.33)
Gender N (%)		
	Female	24 (48%)
	Male	26 (52%)
Ethnicity N (%)		
	Hispanic	20 (40%)
	Non-Hispanic	30 (60%)
Race N (%)		
	White	41 (82%)
	American Indian	4 (8%)
	African American	0 (0%)
	Asian	0 (0%)
	More than one race	5 (10%)
Free Lunch N (%)		
	No	0 (0%)
	Yes	50 (100%)
ELL/LEP Services Received N (%)		
	No	37 (74%)
	Yes	13 (26%)
SPED Services Received N (%)		
	No	39 (78%)
	Yes	11 (22%)
School Attendance M (SD)		150.84 (18.59)

Note. Percentages can exceed 100% as a result of rounding to the nearest whole number.

Table 2. Descriptive Report of Usage by Target and Non Target Samples

	Target					Non Target				
	N	M	SD	Min	Max	N	M	SD	Min	Max
Minutes	50	160.32	79.55	12.93	383.53	163	51.25	37.29	0.28	210.73
Days	50	14.96	7.05	1	32	163	5.06	3.59	1	18
Activities	50	3.84	1.06	2	6	163	2.74	0.9	1	5
Practice Opportunities	50	231.12	89.48	31	479	163	95.24	52.44	1	275
Practice Opps Correct	50	0.74	0.08	0.54	0.91	163	0.84	0.09	0.52	1

Table 3. Dosage Response: Usage Variables and Improvements in Math Outcomes (n = 50)

	Minutes of Use			Activities Attempted			Practice Opportunities		
	b	t	p	b	t	p	b	t	p
ASPENS									
Oral Counting	.07	2.02	.052	5.79	2.21	.034	.08	2.40	.022
Numeral ID	.01	0.52	.609	1.31	0.88	.392	.02	0.97	.340
Magnitude Comp.	.01	1.31	.200	.67	0.84	.405	.01	1.46	.155
Missing Number	.01	0.63	.530	.52	1.32	.197	.01	0.89	.380
Number Line Task	.01	0.39	.701	.05	0.14	.893	.01	0.81	.422
Num. Sense Brief	.01	1.52	.136	.80	1.69	.099	.01	1.43	.161

Table 4. Descriptive Report of KinderTEK Satisfaction Students (n = 50) and Teachers (n = 6)

	Students				
	Really like	Kind of like	Kind of don't like	Really don't like	Decline to state
Like using app	24	12	2	2	10

	Teachers				
	A great deal	A little bit	Not much	Not at all	Decline to state
Like using app	3	2	-	-	1
Like content	3	2	-	-	1
Like functionality	2	2	1	-	1
Supports learners	3	2	-	-	1
Ease of use	1	4	-	-	1
Did students like	2	2	1	-	1
Like pacing	-	2	2	1	1
Like scaffolding	-	5	-	-	1
Like interface	-	5	-	-	1

Figure 1. KinderTEK Instructional System

KinderTEK – **2014**

Teacher Control Panel & Website
• Enter student-information & confirm and/or calibrate student placement
• Monitor student progress
• View, print, email student progress & performance reports
• (Teacher App = data's conduit to server)

Server
• Store user-information & performance data/history
• Lock/unlock activities to fit student needs
• Sync Teacher App and website

Student iPad

Student iPad

Student iPad

Student iPad

Student iPad

Teacher Website

Teacher iPad

Server

Common Core Domains

Counting & Cardinality

Operations & Algebraic Thinking

Number & Operations in Base Ten

Zones

Z1 (#0-10)

Z2 (#11-20)

Z3 (#21-30)

Z4 (#31-100)

Activity phases in Zones 1-4

"I do" (Model)
(Explicit instruction)

"We do" (Lead)
(Scaffolded practice & formative assessment)

"You do" (Test)
(Fluency building & formative assessment; As needed)