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Examining the Influence of a Mobile Learning Intervention on Third Grade Math Achievement

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Abstract

*Third grade students at a Midwestern elementary school participated in a 9-week mobile learning intervention (MLI). Two classrooms used Everyday Math and daily practice using flashcards, etc., to learn multiplication. Two other classrooms used Everyday Math and web applications for the iPod touch for daily practice. MLI students outperformed comparison students on a postintervention multiplication test controlling for several covariates, including prior achievement, home iPod touch use, and previous teacher, among others. The medium-sized performance advantage (*b *= .217) was statistically significant at the .01 alpha level. The MLI influence on the most difficult multiplication items was also statistically significant but less important than the student's demographic profile and the teacher's advanced educational technology degree. Experimental research is needed to assess longer-term achievement effects for diverse student groups and school settings and to explore how teaching and learning occurs in mobile environments above and beyond a particular device. (Keywords: mobile learning, mobile devices, student achievement, program evaluation)*

The Who went mobile in 1971. Band members were in their mid-20s at the time. Today, a younger generation is "Goin' Mobile," albeit with iPhones, MP3 players, gaming devices, and tablet technology. Consider the following: 21% of upper elementary school students have a personal smartphone, a quarter of middle school students have a personal tablet device, and more than half of high school students access the Internet outside of school via 3G/4G mobiles devices (Project Tomorrow, 2012). And, as The Who's generation invested in and valued its mobility (via the automobile), the 21st century student similarly regards his/her mobile device (Wallace, 2011). Traxler (2010) describes the "mobile attachment" this way:

Almost every student owns one and uses one, often more than one. Not only do they own them and use them, but they also invest considerable time, effort, and resources choosing, buying, customizing, and exploiting them. These devices express part or much of their owners' values, affiliations, identity, and individuality through their choice and use. They are both pervasive and ubiquitous, both conspicuous and unobtrusive, both noteworthy and taken for granted in the lives of most—but not all—students. (p. 149)

Mobile Learning

The prevalence of mobile devices among students (Brown & Green, 2010; Johnson, Adams, & Haywood, 2011) and access to the Internet and digital learning resources they provide (Eisele-Dyrli, 2011a; Park, 2011) is spurring schools to reconsider instructional and operational practices. Educators are leveraging this technology to improve student engagement, peer interaction, and collaboration; collect classroom feedback; improve communication; reduce computer costs; and extend the place and time of learning (Allen, 2011; Kolb, 2011; Quillen, 2010; Shuler, 2009). Some are also using mobiles to enhance situated learning. For example, using mobile devices on field trips offers a window to socially construct learning through analytic tools and multimodal applications not tied to classroom spaces (Shuler, 2009). Still others, especially elementary teachers, are using skill development software and digital games to improve learning (Project Tomorrow, 2011).

Mobile Learning Defined

The conceptualization of mobile learning has evolved with the undergirding technology and resulting instructional possibilities. Traxler (2005) offered an early definition that specifically linked educational provision to a handheld device. Peng, Su, Chou, and Tsai (2009) situate the student within a context of ubiquitous and mobile computing technologies where relevant, convenient, expedient, and immediate learning is possible, while Park (2011) defines mobile learning as "the use of mobile or wireless devices for the purposes of learning while on the move" (p. 79).

Wong (2012) offers a learner-centric conceptualization of mobile learning, where continual knowledge construction occurs seamlessly along several dimensions, including location (physical and digital, personal and social, informal and formal), time, pedagogy, and device type, among others. From this perspective, learners "are supposed to be knowledge builders who treat any material that they acquire from the Internet as resources to support their sense making and knowledge construction" (p. E21). Wong also discusses how a cloud-based "learner hub" may be coupled with a smartphone and a laptop computer to form a functional personal learning environment.

Mobile Learning Examples

Students consider the function of mobile technologies differently than their teachers and parents, and much of it is tied to productive learning.

> For today's students, emerging technologies such as mobile learning, online learning, and digital content hold great promise for creating a new

> learning environment that not only engages them in contextually based content, but also enables greater personalization of the learning process and empowers them to explore knowledge with an unfettered type of curiosity that is too often missing from traditional classroom settings. (Blackboard K–12, 2011, p. 3)

Perhaps the most well-established mobile learning initiative is one-to-one computing, in which every student receives a laptop computer for school work. For example, the Irving Independent School District (http://www.irvingisd.net/one2one) issues laptops to high school students to help transform instruction and improve learning. However, although positive results have been experienced by one-to-one implementers, uneven use and high equipment costs tend to diminish gains (Bebell & Kay, 2010; Bebell & O'Dwyer, 2010; Donovan, Green, & Hartley, 2010; Dunleavy, Dexter, & Heinecke, 2007; Goodwin, 2011; Greaves, 2010; Holcomb, 2009; Suhr, Hernandez, Grimes, & Warschauer, 2010; Weston & Bain, 2010).

Using mobile devices for educational gaming is becoming popular in schools too. According to Shin, Norris, and Soloway (2011), "mobile gaming creates an individualized learning environment that allows students to select their own learning paths based on their prior knowledge and learning progress. This flexible approach, linked to prior knowledge, leads to meaningful learning" (p. 468). Oconomowoc High School (http://www.oasd.k12.wi.us/page.cfm?p=5295) uses gaming to teach analytical, creative, logic, and problem-solving skills. Smartcodes downloaded to devices assist in board-game play, and augmented reality games are developed and played on mobiles. Research linking gaming to student achievement is emerging. For example, Young et al. (2012) reviewed more than 300 video gaming studies and found varying degrees of impact based on the academic subject (e.g., more for language and less for math).

The "flipped" classroom takes advantage of students' personal mobile technology and Internet access outside of school. In this model, students learn at home by watching lectures and collaborating with students and teachers via learning management systems and online resources such as Khan Academy (http://www.khanacademy.org). This homework approach frees classroom time for problem solving and project-based learning facilitated by the teacher. Byron High School in Minnesota, USA, recently flipped its math classrooms to improve student achievement and save money on instructional materials by using a free online learning system (Fulton, 2012).

Many schools are incorporating "iTechnology" (e.g., iPod, iPad) in learning activities because of its versatility (e.g., e-reading, calculating, mapping, video and audio recording, Internet browsing, gaming), familiarity to students, and affordability. Banister (2010) also notes the educational potential of software apps designed specifically for these devices:

> In the area of mathematics education, web applications for the iPod touch provide many ways for students to practice and explore computational problems. Flash Math is a basic drill program that presents the user with a set of timed problems. Settings for addition, subtraction, multiplication, and division, as well as choices for the number of place values to include in problems (up to at least 1,000,000,000), the number of problems to present, the time for each problem, and progressive time adjustments, make this application very customizable for the student. Teachers could certainly use this application to provide individual students with the types of arithmetic practice that they need to become more proficient in their mathematics classroom. (pp. 126–127)

The Escondido Union School District's iRead program (https://sites.google.com/a/eusd.org/eusd-iread) uses iPods in primary reading instruction, and the Master's Academy (http://www.mastersacademy.org/article.asp?articleID=75) issues iPads to high school students to "increase students' capacity to be adaptable, to collaborate, to innovate, to create, to be productive, and to engage technology in an ethical manner" (https://edseminars.apple.com/event/Uwl70-m0k4m). Similar to gaming research, the evidence of iTechnology impact on student achievement is limited, given its recency. iRead evaluators report more reading growth for its elementary iPod users compared with non-iPod users. Schneps, O'Keefe, Heffner-Wong, and Sonnert (2010) report a larger gain in content knowledge for students reading with an iPhone/iPod touch over conventional reading.

Research Problem and Questions

The need for empirical research connecting educational technology and student learning is increasingly cited in the literature (Bebell, O'Dwyer, Russell, & Hoffman, 2010; Traxler, 2007). This need is underscored as mobile learning sprouts in PK–12 schools with little evidence to guide implementation decisions. The research that does exist usually describes mobile phone and PDA usage in higher education settings (Wu, Jim Wu, Chen, Kao, Lin, & Huang, in press). This study adds to the literature by examining the influence of a Midwestern elementary school's Mobile Learning Intervention (MLI) on third grade math achievement. Specifically, a regression-adjusted covariate comparison group design (see Henry, 2010) is used to address the following research questions:

1. Does participation in the MLI explain a significant amount of variation on a postintervention multiplication test controlling for several covariates including prior student achievement? If so, what is the influence of the intervention relative to the control variables?
2. Does participation in the MLI explain a significant amount of variation on the most difficult postintervention multiplication items controlling for several covariates, including prior student achievement? If so, what is the influence of the intervention relative to the control variables?

Background

We implemented an MLI for third grade students at Park Elementary during the third quarter of the 2010–11 school year. Park is part of a Midwestern PK–12 school district that features a comprehensive high school, two intermediate schools, and four other elementary schools. The total student population (N = 5,000; White = 92%; male = 51%; economically disadvantaged = 20%; students with disabilities = 14%; English language learners = 1%) reflects the demographics of the city and townships it serves. Educators and administrators are recognized as leading users of instructional and management technology. Recent initiatives include virtual schooling, game-based learning, wireless school networks, and iPads for students with disabilities.

Park Elementary serves more than 500 students in grades PK to 4 (White = 88%; male = 54%; economically disadvantaged = 29%; students with disabilities = 16%; English language learners = 2%). There are 22 students in the average class. All classroom teachers are licensed, and half possess a master's degree. The schoolwide student-to-computer ratio is 5:1. All classrooms are equipped with a computer, a document camera, and high-speed Internet. Technology shared among classrooms includes a mobile smartboard, digital Flip cameras, and a limited number of iPad and iPod devices.

Schoolwide Math Curriculum

Park students are taught math via the Everyday Mathematics (EM) approach (University of Chicago School Mathematics Project). Teachers use whole-group instruction to introduce concepts, followed by small-group or individual instruction. Teachers also communicate the "need to practice math skills" with parents and students via assignment notebooks and newsletters.

Multiplication and division facts are introduced to third grade students during the second academic quarter, whereas more in-depth instruction occurs during the third quarter. Learning goals include automaticity with x0, x1, x2, x5, and x10 multiplication facts and using strategies to compute remaining facts up to 10 x 10. Teachers assess student learning via formative and summative assessments. Students also receive grades for math-related effort and attitude.

Park's Third Grade Mobile Learning Intervention

Two intact classrooms (46 students, two teachers) used EM and daily practice using "business as usual" techniques such as flash cards to learn multiplication. Two other intact classrooms (41 students, two teachers) coupled EM and daily practice using iPod touch devices loaded with selected math apps. The total cost of intervention was $10,319. The iPod touch devices and sync cart accounted for 85% of the total cost. The remaining expense was related to instructional and technical support (see Table 1, p. 66).

Park's third grade teachers decided amongst themselves which two classrooms would implement the MLI. All participating students and

Table 1. Mobile Learning Intervention: Total Cost and Per Student Cost

Item	Cost
iPod touch device	$5,280 ($220 x 24 devices)
Math apps[a]	$39
Sync cart[b]	$3,475
Technical support for startup	$200 (8 hrs. x $25)
Instructional support for startup	$200 (8 hrs. x $25)
6. Ongoing technical/instructional support	$1,125 (1 hr. per day x $25 x 45 days)
Total cost of intervention	$10,319
Total cost of intervention per student	$252

[a] *Seven of 10 apps were "lite" or free versions.*

[b] *Components included the cart ($2,300), laptop ($1,000), and wireless access point ($175).*

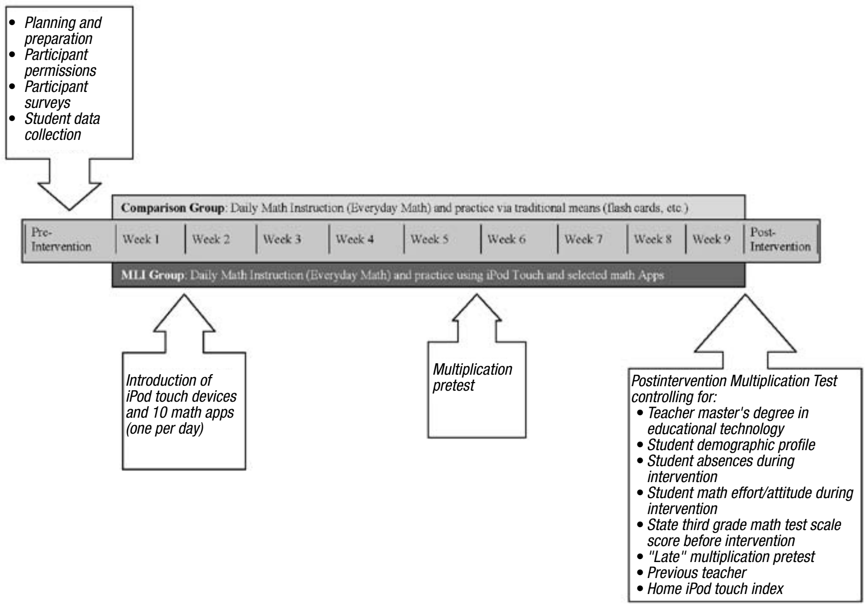

Figure 1. Mobile Learning Intervention implementation timeline.

teachers completed a pre-intervention survey to help identify and control for pre-existing group differences. We also collected a variety of other pre-intervention data (e.g., student test scores, report card data, attendance) from the school's student information system for the same purpose. Classroom teachers administered a 50-item "late" multiplication pretest to all students after the iPod touch devices and math apps were introduced as

Table 2. Study Conditions: Mobile Learning Intervention vs. Comparison Group

	Mobile Learning Intervention		Comparison	
Condition	Classroom 1	Classroom 2	Classroom 3	Classroom 4
School	Park	Park	Park	Park
Grade	3	3	3	3
Classroom Teachers	1	1	1	1
Classroom Technology	PC, Internet, document camera	PC, Internet, document camera	PC, Internet, document camera, interactive whiteboard	PC, Internet, document camera
Math Curriculum	Everyday Math	Everyday Math	Everyday Math	Everyday Math
Daily Math Instruction	1–2 p.m.	1–2 p.m.	1–2 p.m.	1–2 p.m.
Daily Multiplication Practice w/ Flashcards, Fact Triangles, etc.	No	No	Yes	Yes
Daily Multiplication Practice w/ iPod touch Device/Math Apps	Yes	Yes	No	No
Mobile Synch/Operation Cart	Yes	Yes	No	No
iPod touch Device	Yes	Yes	No	No
Pre-Intervention Student Questionnaire[a]	Yes	Yes	Yes	Yes
Pre-Intervention Teacher Questionnaire[b]	Yes	Yes	Yes	Yes
Multiplication Pretest (50 Items)[c]	Yes	Yes	Yes	Yes
Postintervention Multiplication Test (100 Items)	Yes	Yes	Yes	Yes

[a] *The Pre-Intervention Student Questionnaire was given to all students to collect background information and to identify pre-existing group differences that may confound outcomes.*

[b] *The Pre-Intervention Teacher Questionnaire was given to all teachers to collect background information and to identify pre-existing group differences that may confound outcomes.*

[c] *The "Late" Pre-Intervention Multiplication Test was given several weeks into the intervention (after the MLI students and teachers were introduced to the devices and math apps).* Such a strategy is used to improve estimate precision (Schochet, 2010).

another control variable to improve estimate precision (Schochet, 2010). We also administered a 100-item multiplication test to all students at the conclusion of the intervention. Figure 1 depicts the study timeline, and Table 2 compares study conditions for the MLI and comparison groups.

iPod touch Devices for Daily Practice

The school district purchased 24 iPod touch devices for MLI students (see Figure 2, p. 68). Device features included 32 GB storage capacity, a built-in camera with HD video capability, a digital music player, a video player, messaging, an Internet browser, maps, calendars, a game center, a calculator, and an app store. Additionally, the district purchased a wireless mobile cart with an Airport Extreme wireless hub and laptop computer to store, charge and sync the devices. We numbered each iPod touch and assigned it to a specific student for daily practice. The device ID was displayed as wallpaper on the welcome screen.

Figure 2. iPod touch devices used in the Mobile Learning Intervention.

Math Apps for Daily Practice

Each iPod touch device contained the following math apps: Multiplication Genius Lite (Blueonionsoft, Corp., 2009), Mad Math Lite (Lunchbox Apps, 2010), Pop Math (AppBlit LLC, 2009), Flash To Pass (Scybot Technologies, LLC, 2009), Math Drills Lite (Instant Interactive, 2010), Math Tappers: Multiples (HeavyLifters Network, 2010), Multiplication Flashcards To Go (box2 technologies LLC, 2011), Brain Thaw (Groovy Squared LLC, 2009), Math Magic (Anusen Inc., 2010), and FlowMath (palasoftware Inc., 2011). The apps were selected by the district's instructional technology administrator (ITA) and Park's learning resource teacher (LRT), who are contributing researchers to this study, based on several criteria, including curriculum alignment, authentic skill practice, operational ease, and attractiveness to students (e.g., game-like, touchscreen interaction, animated, multimodal, time challenges). The apps also reflected the standards-based multiplication skill practice and mastery expected of all Park third grade students, including logic and problem solving related to repeated addition and multiplication. Figure 3 displays a sample of apps used in the MLI.

Teacher Prep

The ITA prepared a budget, contacted vendors, ordered equipment, acquired apps, and worked with District Technical Support to ready the mobile devices. The ITA also conducted meetings with the LRT and the four teachers to identify and reinforce multiplication topics to be covered during the third quarter. Meetings also focused on use of textbook and math practice materials, establishing that all students would practice 10 minutes each day (using iPod touch devices or traditional means) and that teaching of multiplication facts would be consistent across classrooms.

Brain Thaw (Groovy Squared, LLC)

Flashcards To Go (box2 technologies, LLC)

Multiplication Genius (Blueonionsoft Corp.)

Math Tappers (HeavyLifters Network)

Figure 3. Sample of iPod Touch math Apps used by Mobile Learning Intervention students.

Participant Consent

Student participation was voluntary. The ITA crafted and sent an informational packet to parents. The parents indicated whether their child would participate and returned a signed consent form to the LRT. Parents were also informed that students would complete a pre-intervention survey that included questions about their home technology environment. The participating teachers received a similar informational packet, consent form, and survey notice.

Introducing the iPod touch Devices and Math Apps

Park's LRT was responsible for iPod touch and math app training, coordinating interclassroom iPod touch use, syncing and maintaining cart equipment, and serving as site liaison (i.e., communicating with teachers/parents/administration). Although not part of the formal study, the LRT took field notes for her own reflection. The following excerpt provides insight about initial implementation and use of the mobile devices:

> The two classes that are using the iPod touches were introduced to the touches today. I reviewed "responsible use" using a doc cam, showed students the Pop Math app. I emphasized the goal of the app … to earn

points by popping the factors and correct product, not just moving to the next level, since that can be done by just guessing.

Students came up to the cart to retrieve their iPod touch. Once students had the iPod touches in their hands, I showed them how they could change the settings to "multiplication" and select a particular table that they needed to work on. Students spent ten minutes using the app and, there was no question about student engagement. I also noticed that students self-selected "tables" of numbers that they did not know well.

I introduced an application a day for students to learn and use. A typical day looked like this:

- I rolled the cart into the classroom.
- I introduced one application to the students.
- I did an overview of the application, using a document camera to project the screen of the iPod touch.
- I always emphasized the goal of the application.
- I showed how the application worked.
- I showed how settings could be changed to work on specific tables.
- Students retrieved their iPod touches from the cart and started working on the application as soon as they got to their desks.
- I walked around the room with the classroom teacher assisting students individually.
- We would look at their progress to determine if they were working on tables that were perhaps too difficult or easy.
- I helped students select the right table.
- I helped students with strategies to learn/remember facts.
- Students worked on the iPod touches for 10 minutes.

Daily Math Practice in MLI and Comparison Classes

MLI classrooms. MLI students used the iPod touch devices and math apps to practice multiplication each day. Teachers often directed students to use one or two specific apps during the 10-minute period. On occasion, students were asked to focus on a specific multiplication table. For example, the teacher might ask students to work on 7s using a particular app. Other days, students self-selected an application. Students were never allowed to use more than two apps during a practice period.

Table 3. Pre-Intervention Student Demographics and Achievement: Mobile Learning Intervention vs. Comparison Group

	Mobile Learning Intervention (*N* = 41)	Comparison (*N* = 46)		
Students	%	%	X^2	*p*
Demographics				
Male	56.1	63.0	.435	.510
Caucasian	87.8	95.7	1.804	.179
Economically Disadvantaged	24.4	19.6	.296	.587
Special Education	12.2	17.4	.461	.497
Previous Teacher (Grade 2)[a]				
Teacher 1	22.0	28.3	.457	.499
Teacher 2	26.8	28.3	.022	.881
Teacher 3	22.0	13.0	1.206	.272
Teacher 4	22.0	21.7	.001	.981
Not Enrolled	7.3	8.7	.056	.813
	M	*M*	*t*	*p*
State Math Test Scale Score (Grade 3)[b]	443.8	440.0	2.58	.599

Note. We collected this data from the school's student information system.

[a] *The student's second grade teacher.*

[b] *The state math test is given each fall.*

The LRT worked with teachers to coordinate daily use of the mobile devices. On a typical day, one teacher used the devices after lunch recess. When students completed the 10-minute practice, the cart was rolled over to the other classroom, where students practiced after the formal math lesson.

Comparison classrooms. Comparison students practiced multiplication for 10 minutes each day using "business as usual" techniques (National Center on Response to Intervention, n.d.) such as flash cards, math games, fact triangles, and number sequences. Sometimes students chose their desired method of practice, and other times classroom teachers directed practice. One Comparison teacher provided students with a list of websites for home math practice. The teacher also allowed students to play EM games a few times in the computer lab.

Method

Participants

Students. Eighty-seven students consented to participate in the study (MLI = 41; Comparison = 46), representing 97% of the school's third grade population. The groups appeared well matched on gender, race/ethnicity, economic status, special education status, prior year teacher, and performance on the state-mandated third grade math test (Table 3).

Results from the pre-intervention survey indicated students' home technology environments were similar (Table 4). About two-thirds of students

Table 4. Students' Home Technology: Mobile Learning Intervention vs. Comparison Group

Home Technology	Mobile Learning Intervention ($N = 41$) %	Comparison ($N = 46$) %
How many computers at home?		
3 or more	46.3	41.3
2	29.3	28.3
1	24.4	28.3
0	0.0	2.2
Do you have an iPod touch at home?		
Yes	46.3	52.2
How often do you play with your iPod touch?		
Every day	5.0	13.0
A few times a week	25.0	23.9
A few times a month	7.5	4.3
Hardly ever	12.5	21.7
What do you usually do on your iPod touch?		
Play games	30.0	32.6
Practice math	5.0	4.3
Practice reading	0.0	2.2
Go on the Internet	2.5	4.3
Listen to music	5.0	10.9
Watch videos	5.0	6.5
What other technologies do you have at home?		
iPad	12.5	17.4
iPod or MP3 player	62.5	71.7
Nintendo	70.0	80.4
Wii	80.0	73.9
Xbox	30.0	32.6

Note. We collected this data via the Pre-Intervention Student Questionnaire.

reported having an iPod or MP3 player, and about half reported having an iPod touch. Gaming devices or systems were most prevalent in participants' homes.

Teachers. The four participating teachers, on average, shared similar teaching experience and teaching styles, according to pre-intervention survey feedback (Table 5). The respondents also reported similar perceptions about how mobile devices could influence learning. For example, one MLI teacher wrote, "I think it engages students and helps them to practice skills in a fun way!" and a Comparison teacher noted, "I think the iPod touch will be very engaging for students. They are so comfortable with the technologies, similar to a cell phone, smartphone, video game—all things that they know well."

Table 5. Teacher Characteristics and Technology Use: Mobile Learning Intervention vs. Comparison Group

	Mobile Learning Intervention ($N = 2$)		Comparison ($N = 2$)	
Teacher	Classroom 1	Classroom 2	Classroom 3	Classroom 4
Gender	Female	Female	Female	Male
Teaching Experience	21 yrs.	14 yrs.	12 yrs.	19 yrs.
Teaching Style	Student-centered/ differentiated	Student-centered/ differentiated	Student-centered/ differentiated	Student-centered/ differentiated
Advanced Technology Degree	---	Master's	Master's	---
Technology-Related Professional Development:	---	Blogs, wikis, Jing	---	Interactive whiteboard
Technology Expectations for Students:	Word processing, Internet for research and math practice	Websites for math skill practice	Word processing, Internet for research and math practice	Word processing, Internet for research
Type of Technology Use in the Classroom	Internet	Internet	Internet, interactive whiteboard, iPods	Internet
Frequency of Technology Use in the Classroom	Rarely as whole class	Weekly	Daily	Daily
How Will the iPod touch Improve Learning?	Motivational tool	Engage students	Engage students	Excellent tool for students
Home Technology Use	Personal computer—used daily, and iPod—used four to five days a week	I have a laptop, Nook, Wii, DSI, iPod. We use these daily!	Wireless laptops, smartphone, GPS, iPods—use it often every day	Home computer daily, searching for information and enhanced communication

Note. Data collected via the Pre-Intervention Teacher Questionnaire.

In contrast, the Comparison teachers reported using technology more frequently in their classrooms, mostly for word processing and Internet research. One Comparison teacher explained, "I use technology with my students on a daily basis; this is more than in past years. This is my first year with a Smart board in my room and with iPods in my room. In the past I would use the Smart board for certain lessons in a unit; now I use it almost daily." Conversely, one MLI teacher responded, "I only have one computer in my room, which makes it hard, because only one or two students can use it at a time."

Dependent and Control Variables

Dependent variable. We constructed a 100-item postintervention multiplication test (64 single-digit items, 36 double-digit items), and the ITA administered it to students in a group setting under standardized conditions after reading a test administration script to the test-takers that said, for example, "You will have 10 minutes to answer as many problems as you can. Don't worry if you are unable to finish the entire test. Just do your best work." The ITA collected the tests, and we hand-scored them and entered the scores into SPSS for analysis.

Control variables. We included several variables in the analytical model to help control for pre-existing group differences (Table 6, p. 74). We selected the variables, collected during the pre-intervention phase, for intervention

Table 6. Control Variables

Variable	Data Source
1. Teacher Master's Degree in Educational Technology (1 = Classroom 2 + Classroom 3, 0 = Classroom 1 + Classroom 4)	Pre-Intervention Teacher Questionnaire
2. Student Demographic Profile (1 = White + male + regular education + regular lunch, 0 = not)	Student Information System
3. Student Absences During Intervention (Number of days)	Student Report Card
4. Student Math Effort/Attitude During Intervention (1 = Satisfactory or excellent, 0 = not)	Student Report Card
5. State Third Grade Math Test Before Intervention (Scale scores)	Student Information System
6. "Late" Multiplication Pretest (Number items answered correctly)	Mobile Learning Intervention
7. Previous Teacher (Grade 2) (1 = Teacher 3, 0 = Teacher 1 + Teacher 2 + Teacher 4 + not enrolled)	Student Information System
8. Home iPod touch Index (0–8) iPod touch device (1 = iPod touch, 0 = not) iPod touch use (1 = everyday, 0 = not) iPod touch to play games (1 = play games, 0 = not) iPod touch to practice math (1 = practice math, 0 = not) iPod touch to practice reading (1 = practice reading, 0 = not) iPod touch for internet (1 = Internet, 0 = not) iPod touch for music (1 = listen to music, 0 = not) iPod touch for video (1 = watch video, 0 = not)	Pre-Intervention Student Questionnaire

Note. Independent variable: MLI participation (1= Classroom 1 + Classroom 2, 0=Classroom 3 + Classroom 4). Dependent variable: post-intervention multiplication test.

relevance (e.g., prior student achievement, student demographics, absence during intervention) and sample-size considerations. Generally speaking, 10–15 participants are recommended for each control variable (Shultz & Whitney, 2005; Song & Herman, 2010; Stevens, 1996). We administered a "late" pretest to students after MLI students were introduced to the mobile devices and math apps. The timed, paper-and-pencil 50-item multiplication test mirrored the posttest in form, content, and standardized administration.

Data Analysis

We used measures of central tendency to describe test performance. We used Ordinary Least Squares multivariate regression analysis to estimate MLI influence on postintervention test performance. We used standardized beta to identify the magnitude of MLI influence. We also calculated Cohen's *d* to facilitate effect size comparison with other technology interventions. In this case, the unstandardized regression coefficient (*B*) was divided by the standard deviation of the dependent variable.

Table 7. The Influence of MLI Participation on a Postintervention Multiplication Test: Total Items Answered Correctly

Model	*B*	*p*	*b*	95% CI for *B*
Constant	-29.152	.084		
Mobile Learning Intervention	7.259	.002	.217	[2.83, 11.68]
Advanced Technology Degree	4.705	.037	.141	[0.29, 9.11]
Demographic Profile	2.205	.331	.065	[-2.28, 6.69]
Student Absences	-.289	.518	-.042	[-1.17, 0.59]
Math Effort/Attitudes	8.723	.003	.208	[3.08, 14.35]
State Math Test	.092	.023	.185	[0.01, 0.17]
Late Pretest	.899	.000	.588	[0.64, 1.15]
Previous Teacher	5.268	.062	.119	[-0.27, 10.80]
Home iPod touch Index	.985	.280	.070	[-0.81, 2.78]
Adjusted R^2	.681			
F	21.371	.000		

Note. *N* = 87. CI = confidence interval. Adjusted mean predicted test scores for MLI students (*M* = 54.5, *SD* = 14.8) and Comparison students (*M* = 46.3, *SD* = 12.5). *d* = 0.45, 95% CI [0.02, 0.88].

Results

Does participation in the MLI explain a significant amount of variation on the postintervention multiplication test? If so, what is the influence of the intervention relative to the control variables?

On average, MLI students answered more items correctly on the postintervention multiplication test (*M* = 54.5, *SD* = 14.8) than the Comparison students (*M* = 46.3, *SD* = 12.5). We entered the independent and control variables in a single step for the regression analysis. Influence and multicollinearity diagnostics were not significant. The analytical model explained 68.1% of variance in the total number of multiplication items answered correctly (Table 7). The medium-sized performance advantage for MLI students (*b* = .217) was statistically significant at the .01 alpha level. MLI participation was the most influential "explainer" of test performance excepting the pretest. The student's math-related effort/attitude grade was also an influential predictor of test performance (*b* = .208).

Does participation in the MLI explain a significant amount of variation on the most difficult postintervention multiplication items? If so, what is the influence of the intervention relative to the control variables?

We repeated the analysis using double-digit multiplication items as the dependent variable. MLI students answered a greater number of these items correctly (*M* = 11.6, *SD* = 4.9) than the Comparison students (*M* = 8.2, *SD* = 4.4). Casewise diagnostics identified one significant outlier (one MLI student answered all items correctly), which we excluded from the regression analysis. The resulting model explained 42.9 % of variance in the outcome measure (Table 8, p. 76). MLI participation was a significant predictor of test performance but was less influential (*b* = .201) than several

Table 8. The Influence of MLI Participation on a Postintervention Multiplication Test: Double-Digit Items Answered Correctly

Model	*B*	*p*	*b*	95% CI for *B*
Constant	-8.611	.317		
Mobile Learning Intervention	2.542	.028	.201	[0.28, 4.80]
Advanced Technology Degree	2.653	.021	.210	[0.41, 4.89]
Demographic Profile	2.754	.019	.213	[0.47, 5.03]
Student Absences	-.158	.486	-.061	[-0.60, 0.29]
Math Effort/Attitudes	.781	.588	.049	[-2.07, 3.63]
State Math Test	.013	.517	.068	[-0.02, 0.05]
Late Pretest	.285	.000	.481	[0.15, 0.41]
Previous Teacher	2.709	.060	.163	[-0.11, 5.53]
Home iPod touch Index	.586	.207	.110	[-0.33, 1.50]
Adjusted R^2	.429			
F	8.088	.000		

Note. $N = 86$. CI = confidence interval. Adjusted mean predicted test scores for MLI students ($M = 11.6$, $SD = 4.9$) and Comparison students ($M = 8.2$, $SD = 4.4$). $d = 0.30$, 95% CI [-0.12, 0.73].

control variables, including the student's demographic profile ($b = .213$) and whether the classroom teacher had an advanced educational technology degree ($b = .210$).

Discussion

Students are "goin' mobile" across the United States, and educators are adjusting instructional and operational practices to reap learning benefits. Most available research about mobile learning has focused on cell phone and personal digital assistant (PDA) use in higher education settings (Wu et al., in press). Little research has been conducted in PK–12 settings or directed toward a particular academic subject area. The current study adds to the literature by examining the influence of a Midwestern elementary school's Mobile Learning Intervention (i.e., using iPod touch devices and selected apps for daily multiplication practice) on third grade math achievement.

Key Findings

MLI students outperformed Comparison students on a postintervention multiplication test controlling for prior student achievement and several other covariates. This finding suggests that coupling "business as usual" curriculum with a mobile device may be a cost-effective lever to improve student achievement. The costs and outcomes of the evaluand's MLI also compare favorably to those of alternative programming. This is an important criterion for judging merit and worth (Harris, 2009; Hill, Bloom, Black, & Lipsey, 2007). For example, the MLI cost per student ($252) is fiscally preferably to one-to-one laptop programs and similar initiatives that require significantly more investment in hardware, software, and technical support. The MLI effect size ($b = .217$ or $d = 0.45$) also matches up with alternatives like online learning, $d = 0.24$ (U.S. Department of Education, 2009); Computer-Managed Learning, Comprehensive Models, and Supplemental Computer-Assisted Instructional Technology, $d = 0.17$ (Cheung & Slavin, 2011); and instructional technology in general, $d = 0.41$(Waxman, Lin, & Michko, 2003).

We parsed MLI influence on the most difficult multiplication test items and found it to be statistically significant. Several control variables were also influentional explainers, including student demographics and advanced teacher training. This finding suggests that in-class mobile learning may foster and sustain productive student-teacher learning interactions.

Implications for Practice

The current study has several implications for practitioners. First, effective implementation of mobile learning depends on administrative and school commitment and adequately trained teachers in matters of pedagogy, instructional technology integration, classroom management/facilitation, and mobile device operation. Second, an onsite resource person, like Park's LRT, is needed for teacher support, device management and trouble shooting, software/app selection, and stakeholder communication. The resource person may also facilitate a student's out-of-school use of mobile devices and family involvement in related learning assignments.

Adopting a bring your own device (BYOD) model may improve device accessibility while allowing the school to downsize its own hardware inventory. Similarly, sharing devices during an instructional or practice period may reduce hardware costs. Such a 1 :> 1 model can be advantageous from a pedagogical, collaborative, and productivity perspective (Larkin, 2011). And finally, a program evaluation plan should be formulated and executed for improvement and accountability purposes.

Limitations of the Study

We used a regression-adjusted covariate comparison group design to examine the MLI influence on student achievement. As in all nonexperimental research, pretreatment group differences may confound posttreatment outcomes (Cook & Campbell, 1979). Pre-intervention data were collected to help identify and control for this threat. MLI participants were similar on measures of demographics, home technology use, enrollment history, and prior achievement. Teachers also appeared similar on most pre-intervention survey responses, including teaching experience and teaching style. In addition, using a local comparison group and making statistical adjustments based on background variables, both used in the current study, reduce design bias (Glazerman, Levy, & Myers, 2003).

We conducted the MLI over a relatively brief period under positive conditions. Such studies tend to produce better outcomes due to novelty effects and hyperattention to intervention details (Cheung & Slavin, 2011). For the current study, novelty effects may be diminished, given the high percentage of participants reporting ownership of a personal iPod touch. In addition, a limited amount of iTechnology was available to classrooms for podcasting, etc. Park's LRT may have affected study outcomes. This "second teacher" introduced math apps, provided technical support, and supported the intervention on an as-needed basis. However, it should be noted that instructional support was minimal or absent beyond initial app training.

And, whereas some may discount results of "best case" interventions, others argue that evaluation should begin within an optimal context before proceeding to a typical educational setting. As stated by Song and Herman (2010):

> If an intervention has been found effective under ideal conditions, and the intervention itself has not changed substantially from what was tested in efficacy trial(s), the next logical step is to assess its impact under typical implementation conditions. (p. 362)

Research consumers should also recognize that smaller studies (<250 participants) tend to yield larger and more variable effect size estimates. For example, Slavin and Smith (2009) report an overall negative correlation (-.28) between sample size and pretest adjusted effect size. As presented above, the current study compares favorably to alternative programming, and the effect size confidence interval for total multiplication items answered correctly did not contain the zero point suggesting a positive effect.

Finally, this study did not, in effect, evaluate how learning occurred in the mobile environment. For example, the teacher's role during mobile practice sessions was not a study focus.

Recommendations for Future Research

Experimental research at the classroom and school levels is required to confirm and extend results of the current study. Attention should be paid to the interaction of mobile learning and several covariates, including student demographics, student math-related effort/attitude, and teacher instructional technology background. Further cost analysis is needed to assist policy-related decisions and provide data for cost benchmarking (Harris, 2009).

Additional study is also needed to evaluate how teaching and learning occurs within and across mobile environments. Wong's (2012) multidimensional view of mobile learning may be a useful architecture to guide this inquiry. Possible research questions include:

- Does mobile learning lend itself to a particular grade level, subject area, or instructional approach?
- How might mobile learning affect assessment practices?
- How might mobile learning affect traditional class schedules, student and teacher attendance requirements, and class size conception?

- What type of school network configuration and acceptable use policies best serve mobile learning?
- How might schools partner with families and communities to facilitate learning outside the classroom via mobile technologies?

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