Onebillion Math Software

David Livingstone Community School

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Preface

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Project Abstract

This evaluation assesses how using Onebillion's math software affected the math abilities of an experimental group of 19 kindergarten students at David Livingstone Community School in the Lord Selkirk Park area of Winnipeg, Canada. Over a period of nine weeks between April 3rd and May 31st, 2018, the students' mathematics abilities were tested before and after the Onebillion intervention; these results were then quantified and compared those of a control group (n=18) who had been receiving standard face-to-face instruction. The material covered by the experimental group and the control group was consistent with the provincial curriculum for math instruction at that grade level. The selected study design allowed us to evaluate whether the tablet-based math app helped the experimental group outperform the age-matched control group in terms of learning achievements. The post-test results revealed improved performance by both groups, with the experimental group outperforming the control group on all indicators by a statistically significant margin. These results are discussed in relation to the Onebillion math app's potential to stimulate student interest in math, optimize their learning experience, and help develop their math competence. Ultimately, the goal of this study was to explore a potentially effective and engaging tool for improving academic standards in the early years and eventually closing the high school graduation gap, which persists in large part due to poor performance in mathematics.

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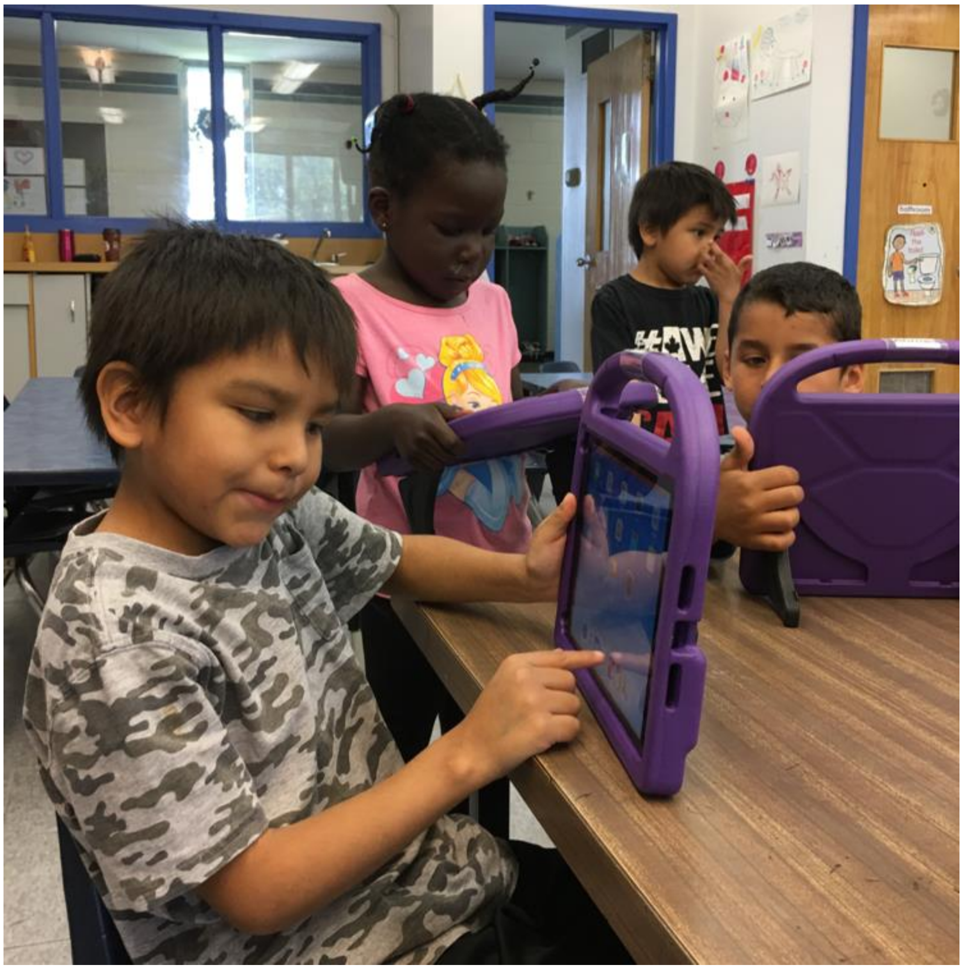

Executive Summary

Over the past few decades, there has been growing interest in tablet-based math apps as a best practice in math education. This evaluation measures the effects of Onebillion's tablet-based math software on an experimental group of 19 kindergarten students at David Livingstone Community School in the Lord Selkirk Park area of Winnipeg, Canada. Over a period of nine weeks between April 3rd and May 31st, 2018, the experimental group's mathematics abilities were tested before and after the Onebillion math app intervention; these results were then quantified and compared to those of an age-matched control group (n=18) who had been taught the same material via the standard, face-to-face instructional approach. This study design was selected because it allowed us to evaluate whether practicing on a tablet-based math app could help young students realize greater learning gains than traditional classroom instruction. Our findings showed that both groups demonstrated improved performance on their post-tests, with the experimental group outperforming the control group on all indicators by a statistically significant margin. These results are discussed in relation to the Onebillion math app's potential to stimulate student interest in math, optimize their learning experience, and help them develop math competence. Ultimately, the goal of this intervention was to help improve academic standards in the early years and to eventually close the high school graduation gap, which continues to persist in large part due to poor performance in mathematics.

Key Findings

This study produced a number of encouraging findings.

- As expected, the experimental group showed a greater overall % change than the control group in average score from the pre-test to the post-test at +30.4% to +10.3%, respectively. Notably, while the experimental group scored only slightly higher than the control group in the pre-test (2.7 points higher average points or 11.6%), their scores were considerably higher in the post-test (8.2 points, or 31.9% higher than the control group's average score).
- The most significant outcome of this study was the huge improvement in learning and test performance made by those students in the experimental group who had struggled on the pre-test (a score of 50% or lower). Despite the relatively short seven-week span between the pre- and post-test, these students' post-test scores increased by an average of 49.5% (range: 12.5-154.5%). In fact, these students performed better than the stronger experimental group students (pre-test scores exceeding 50%) who achieved a 15.4% average increase on the post-test (range: 2.4-33.3%). These results exceeded expectations by far, and they are consistent with other research that has reported similar substantial learning improvements in students who struggle in math.
- Improvements in the experimental group's math skills were in the areas of pattern recognition (e.g. triangle, triangle, rectangle); early pre-proportional reasoning (e.g. same as, more than, fewer than); simple arithmetical learning

(e.g. one more than/one less than; two less than); basic arithmetic visualization (e.g. I have 8 cats and take away 3); number recognition and counting to 20; and telling time on a clock. Many students in the experimental group performed these tasks at a Grade 1 level or higher, while the control group showed improvement in areas mostly related to the kindergarten math curriculum (e.g. counting to ten; size attributes, number recognition, etc.).

- Some gender differences were also observed. The girls in the experimental group outperformed the boys in both tests (Pre-test: 5.3 points higher; Post-test: 2.7 points higher). However, the gap between the boys and girls narrowed after the post-test, which suggests that the boys made significant learning gains from practicing with the math app. Similarly, the girls in the control group also outperformed their male counterparts in both tests (Pre-test: 5.3 points higher; Post-test: 5.9 points higher), but, unlike the experimental group, the gap did not close following the post-test.
- Post-test results were much more strongly related to the number of ‘stars’ awarded to students after completing one of the 10 modules than they were to student attendance. While there was a small and insignificant correlation between school attendance rates and post-test scores in the experimental group, there was also a statistically significant positive correlation between post-test scores and the number of stars awarded to the student. This finding suggests that the individualized learning opportunities offered by tablet-based interventions can help to accommodate diverse student needs and circumstances, such as spotty attendance rates, while still helping to develop math proficiency.

Another significant outcome was that the Onebillion app challenged students in the experimental group to perform above their grade level. Examples of areas where this was observed include:

- Positional words, such as left, right, and middle;
- Grade 1 counting and basic arithmetic learning, e.g., 2 less than 5; arithmetic visualization, e.g., I have 4 fish and I add 4 more. How many fish do I now have;
- Equal sharing, e.g., I have 6 candies. How do I share them equally between 2 children; and
- Skip counting, ordinal numbers, and telling time on an analogue clock.

In helping them exceed the curricular requirements for their grade level, the Onebillion app helped to prepare these students to enter Grade 1 with confidence in their mathematical abilities.

Onebillion Math Software at David Livingstone Community School

Context

Over the past few decades, mobile technologies, including tablet-based math applications (apps), have received increasing attention for their usefulness in improving the educational outcomes of young children, particularly those in high-poverty regions (Outhwaite et al., 2017; Pitchford et al., 2018; Pitchford, 2015). Younger students are naturally drawn toward these technologies, and educational publishing companies have responded accordingly. The literature identifies a number of key advantages to these learning tools, including: individualized learning opportunities that can accommodate diverse learning needs; access to a large range of practice problems that are delivered in a playful format; built-in student assessment data and immediate feedback (both positive and negative), which tends to improve student engagement; and relatively minimal required adult supervision, which is especially important in large classrooms (Evans et al., 2014; Pitchford, 2015; Stacy et al., 2017). Notably, barriers to implementation have included insufficient school funding to cover the costs of acquiring and maintaining the tablets, unreliable internet availability in some regions (e.g. Northern Manitoba), low rates of school attendance in some areas, and inadequate support for educator training and preparation (Okolo & Diedrich, 2014; Stacy et al., 2017).

For its part, Onebillion is a London, UK-based charity and not-for-profit educational publishing company that develops tablet-based numeracy software for primary school children between the ages of 3 and 6. As its name suggests, the Onebillion intervention's main objective is to reach one billion marginalized children throughout the world, and it launched this effort by successfully pilot-testing its math app via randomized control trials in Malawi, a country in the developing world (Pitchford, 2015), and in Nottingham, a below-average income area in the U.K. (Outhwaite et al., 2017). Since these initial trials, the Onebillion math app has been localized into more than 50 languages, and it has been adopted by schools throughout Malawi, as well as in other pilot projects in South Africa, Cambodia, Ethiopia, and Uganda. In addition to its advantages as an educational tool, downloading the app to a touch-screen device, such as an iPad, is a relatively easy and user-friendly process (see https://onebillion.org/apps), which has likely contributed to its appeal. Thus, this educational software is totally transferable to many different social and economic contexts, and it can be accessed and used by people with a wide range of technological abilities.

While Onebillion also offers a math app for children ages 4-6, the app used in this study was the one designed for 3-5 year olds. This app is described by its developers as being child-centered in design and consisting of a number of different measures of early years mathematical ability, such as: sorting and matching; counting (to 3, 5, 7, 10 etc.); comparing items; recognizing different sizes, lengths, patterns, and shapes; and simple addition and subtraction. In addition, the content is interactive, colorful, animated, and non-language based, as the student is verbally guided through the exercises by instructions provided by an audio narrator. The software aims to develop the user's memory and visual attention to detail, manual coordination, and ability to count precisely, among many other competencies. Moreover, the Onebillion math app satisfies the provincial curriculum requirements for kindergarten mathematics (Manitoba Education and Advanced Learning, 2014), which makes it suitable for use in conventional classrooms.

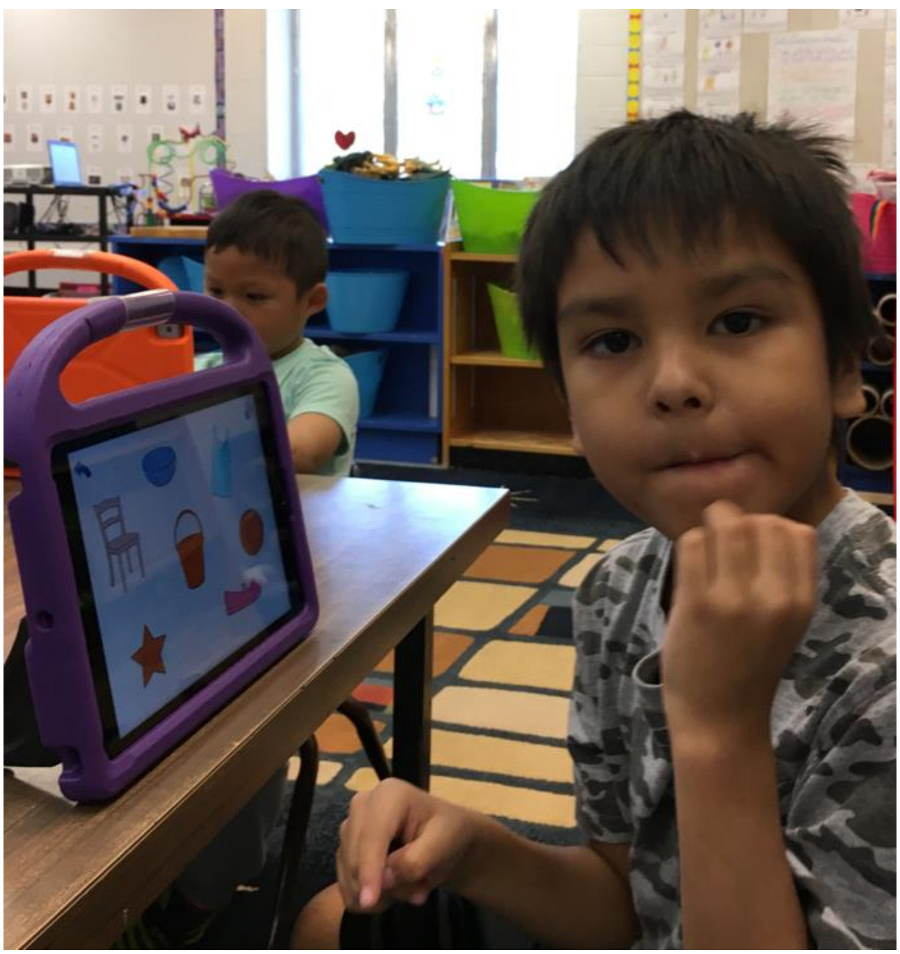

Table 1 outlines the context in which the project was realized at David Livingstone Community School in Winnipeg, Canada.

Table 1: Context in Which the Project was Realized

	Description	**N=**	**%**
Indigenous language groups	n/a	-	-
Province and region	Winnipeg, Manitoba, Canada	-	-
Number of students the organization serves each year: David Livingstone Community School (1)	Nursery to Grade 8 Elementary: Nursery to Grade 6	338 272	
Average number of people the organization serves each year (measured by the approximate population in Lord Selkirk Park in the 2011 Census)	Students, siblings and parents/guardians	1,500	
Percentage of elementary students who are Indigenous (1)		245	90.0%
Percentage of elementary students who are new Canadians (2)		24	8.4%
Percentage of elementary students in care (1)		21	7.7%
Development focus of the Onebillion math app software	Early years: kindergarten	-	-
Number of elementary school participants in the program evaluation	Onebillion at David Livingstone School (kindergarten classes)	37	13.6%
Years in operation	The school opened in 1922	96 years	-
Learning Environment	School readiness in numeracy.		
Category of Indigenous educational practice applies to this project	Indigenous ways of knowing: experiential, hands-on learning; formal and informal knowledge.		
(1) Personal communication with Patricia Mainville, Vice-Principal, David Livingstone School. (2) Retrieved from the Winnipeg School Division's Student Demographic Report, 2016-17.			

History of the Project

The Onebillion math app was introduced to David Livingstone Community School through Timothy Millican and Chipman Family Foundation Director, Susan Millican, whose organization generously funded the acquisition of 20 iPad tablets. Through Indspire and the Winnipeg Foundation, connections were made with Timothy Cox (Principal) and Patricia Mainville (Vice-Principal) at David Livingstone Community School. When asked what had piqued his interest in doing a pilot-test with the app in Winnipeg, Mr. Millican explained:

> "Like much of the world, significant disparities in the distribution of resources are endemic to Manitoba; such disparities inevitably result in unenviable—and perhaps avoidable— impacts on the educational experiences of many Manitoban children. After reading about the success of the Onebillion program in Malawi, it occurred to me that—although they were very different environments—the principles at play should well remain the same. It seemed that, as in Africa and the United Kingdom, the Onebillion program held the promise of having a demonstrable, affordable impact on the first experiences of many young students with mathematical curricula. Accordingly, and at the very least, it struck me as worthwhile to arrange to evaluate this possibility within the context academic research. Subsequently, I contacted Andrew Ashe (Onebillion's CEO), who was happy to provide free licenses for the Onebillion software and to encourage our independent review of its efficacy." (Personal communication with Timothy Millican, June 11, 2018).

Thus, the theory behind the pilot-test was that the Onebillion tablet-based math app could potentially offer an innovative approach to improving math proficiency due to its ability to provide students with individualized instruction based on their unique needs. The app allows students to practice the material in each unit as much as they would like, but they cannot move on to the next unit until they have demonstrated mastery of the material by passing a quiz with 100% accuracy. Furthermore, the software also provides positive academic feedback as the student works through each unit, which is an integral element in developing student motivation and mathematics proficiency (Kiru et al., 2018). Consequently, it was expected that allowing students to use the app to practice their math skills at their own pace would result in higher mathematics scores and more confidence with regards to academic activities in general.

Learning through a hands-on approach is consistent with Indigenous ways of knowing. For example, using physical materials while learning mathematical concepts promotes mastery of skills, and showing practical applications of complex ideas helps to build self-esteem in students. A hands-on approach teaches students how to develop strategies and creative solutions to solve problems or tasks, and it encourages them to embrace challenges rather than give up. In addition, the use of concrete examples in teaching basic math skills helps students become more independent as learners and instills feelings of success with regards to their own math performance. This is particularly important for students from low-income neighborhoods, as there is a well-established and strong correlation between socioeconomic status and math test scores (Anders et al., 2012). For this pilot project, it was strongly believed that using the Onebillion app to allow each student to go at their own pace would narrow the gaps in academic achievement resulting from socio-economic status, EAL (English as an Additional Language) status, or individual academic strengths.

Socio-Economic Geography of the Area

The Lord Selkirk Park community surrounding David Livingstone Community School is increasingly becoming more diverse as a result of the rapidly growing population of urban Indigenous peoples—primarily First Nations and Métis—and new Canadians, who together represent the fastest growing populations in both the immediate neighbourhoods and Canada as a whole. Indeed, Indigenous people represent 11% of Winnipeg's population and account for 20.6% of inner-city residents, while new Canadians comprise almost one quarter of inner-city residents (City of Winnipeg, 2015a). In Lord Selkirk Park, Indigenous people and visible minorities represent 55.7% and 13.9% of the population, respectively. According to the 2011 Census, Lord Selkirk Park's population of recent immigrants mainly consisted of people from the Philippines (37.0%), Iraq (18.5%), and various African nations (44.4%) (City of Winnipeg, 2015b), with newcomers from Syria having become increasingly prominent in recent years.

Despite the local cultural richness and diversity, these surrounding neighbourhoods are high-poverty areas that struggle with social inequities, such as inadequate housing and high unemployment that negatively affect the learning environment for local students. In the 2011 Census, 59.3% of households in Lord Selkirk Park qualified as low-income[1], reporting a median household income of $17,252 compared to $57,925 for the City of Winnipeg as a whole. Furthermore, 53.1% of household income in the Lord Selkirk Park area was derived from government transfer payments (City of Winnipeg: 11.6%) (City of Winnipeg, 2015b). Winnipeg is located in a province (Manitoba) that is frequently referred to as the child poverty capital of Canada, as 62% of First Nation children live below the poverty line compared to 15% of non-Indigenous children (Macdonald, & Wilson, 2013). Approximately two-thirds of elementary students at David Livingstone Community School live in single-parent families, and 66.9% live in families with incomes below LICO (Winnipeg School Division, 2016-17 Demographic Report, 2017).

Not only are Indigenous youth hampered by the enormous economic disadvantages associated with poverty, but they also experience higher school dropout and pushout rates than children and youth in more affluent neighbourhoods. These challenges are particularly significant in the Winnipeg community because it has the largest Indigenous population of all the major Canadian cities, with 50% being younger than 25 years of age (Statistics Canada, 2013b). Moreover, as a percentage of all Indigenous peoples in Winnipeg, the number of Indigenous youth under the age of 18 is more than double that

[1] Based on Statistics Canada's 2011 after-tax low-income measure (LIM-AT).

of their non-Indigenous counterparts (35.4% and 17.2%, respectively) (Statistics Canada, 2013a, 2013b).

A Manitoba study found that high school completion rates in the poorest urban families (i.e. lowest income quintile) could be as low as 55.3%, which stands in sharp contrast to the 98.5% completion rate recorded in the highest income quintile (Brownell et al., 2012, p. 207). In Winnipeg, students who fail to complete high school frequently come from Indigenous families. In addition to being forced to contend with the barriers associated with poverty, these students also face numerous barriers in the educational system, such as an absence of cultural content and high levels of distrust resulting from the legacy of residential schools. In Lord Selkirk Park, 56.6% of the population has no post-secondary certificate or high school diploma, and only 8.2% of the population aged 15 years and over holds a bachelor’s degree or higher (City of Winnipeg, 2015b). Likewise, in Winnipeg, a large gap persists in university completion rates between Indigenous and non-Indigenous people at 12.3% and 30.4%, respectively (Statistics Canada 2013a, 2013b, 2010; Hallett, 2006). Thus, this disparity results in the potential loss of economic and social contributions from the fastest growing segment of the community.

Brief Review of the Background Literature on Tablet-Based Math Interventions
Studies conducted in a range of countries have consistently demonstrated that student difficulty with math is a shared educational policy problem. In response to this global problem, Pitchford (2015) has argued that “radical shifts in the teaching of mathematics are needed […] to raise academic standards” (p.2). A relatively new area of research has focused on students’ early years academic development using tablet-based interventions (Bruhn et al., 2017; Cumming et al., 2014; Gunderson et al., 2017) and computerized interventions in kindergarten classrooms (Praet & Desoete, 2014). Evidence-based studies in this area have consistently found these instructional strategies to be beneficial in creating a strong foundation in mathematical thinking in young children (Hawkins et al., 2016; Kiger et al., 2012; Outhwaite et al., 2017; Park et al., 2016). For example, Pitchford (2015) conducted a randomized control trial to examine the effectiveness of the Onebillion tablet-based math intervention in over 300 primary school children in an impoverished region of Malawi. Her findings revealed that the students who had used the math app for 30 minutes each day for 8 weeks showed greater gains than the students in the control group, who had simply received standard, face-to-face instruction. In another example, Riconscente (2013) found that fourth grade students who played an iPad fractions game over a 5-day period showed 15% more improvement in their fractions test scores than the control group. Moreover, the game also had the effect of improving their attitudes toward fractions, producing a statistically significant increase of 10%.

Other studies suggest that students from low-income areas can benefit from early years tablet-based math interventions, as they frequently trail behind their middle-to-high income counterparts at the start of kindergarten (Park et al., 2016; Schacter et al., 2016). It is well-established that math proficiency during the early educational years is a key predictor of later academic achievement in both math and other science, technology, engineering and mathematics (STEM) fields as well (Park et al. 2016). Knowledge of mathematical concepts tends to be acquired on a cumulative basis, with each new concept becoming a building block on which the next will rely. Therefore, it is critical that students keep up with the incremental progression involved in mathematical instruction, as disruptions to this progression are likely to reinforce math anxiety and resistance toward academic activities, which in turn can cause struggling students to fall further and further behind their classmates. The necessity to keep pace becomes ever more critical as students begin to enter the higher grades because the disengagement and academic apathy that result from falling too far behind inevitably become significant obstacles to finishing high school (Beilock & Maloney, 2015; Duncan et al., 2007).

Other studies have noted that the complexity and conceptual challenges of math require greater amounts of mental resources than reading (Stacy et al., 2017), and some researchers have even suggested that early math performance may be a significant predictor of later literacy skills (Duncan et al., 2007; Purpura et al., 2017). Thus, it is not surprising that students who have difficulties with math (and literacy) require more support than other students in finishing high school. The need for continuity in math skills can be supported by using tablet-based math interventions in the early years, as such interventions will help ensure that students do not fall behind as a result of failing to learn all the necessary steps. Consequently, the use of tablet-based math interventions may strongly predict math and reading achievements in the middle and high school years (Park et al., 2016; Purpura et al., 2017).

Nevertheless, longitudinal studies are required in order to test this predictive relationship in more depth, as it remains unclear whether early years math measures adequately account for language skills; since elementary level math is highly language-based, it may serve as a proxy measure for language skills, which in turn could put EAL students at a disadvantage. Moreover, reading and math assessments may capture more complex skills, such as critical thinking and comprehension (Purpura et al., 2017), which are both critical to future academic performance. As such, tablet-based technologies could become an indispensable tool that would help teachers address the gaps in the educational experience of EAL and other students with language-based challenges who need extra help to catch up to their peers.

Researchers have also noted that the inaccessibility of core curricula, including math, is a critically important challenge for students with disabilities (Burton et al., 2013; Cumming et al., 2014; Okolo & Diedrich, 2014; Pitchford et al., 2018). Evidence-based research, including randomized control trials, has demonstrated the positive effects of using technology to support students who have mathematics learning disabilities, broader cognitive disabilities, or general difficulties in learning mathematics (Burton et al., 2013; Cihak et al., 2010; Kiru et al., 2018). In one such study, Burton et al. (2013) found that a tablet-based intervention was effective in helping students with behavioral challenges stay on task, which ultimately led to improvements in their academic performance.

Activities Accomplished

The researchers obtained permission to conduct their study, which utilized an experimental research design, from the Winnipeg School Division and David Livingstone Community School. Written consent was obtained from the children's parents or legal guardians, resulting in a total sample of 39 students from four kindergarten classrooms at the school. To assess their starting knowledge base, all 39 students participated in the pre-test exercise, which was a traditional paper and pencil test that was administered by the evaluator with the assistance of a Learning Support Teacher and a volunteer research assistant. The pre-testing stage took place on April 3rd, 4th, and 6th, 2018. Since two students who were assigned to the control group moved to a different school after pre-testing, the post-testing stage, which was conducted on May 24th, 29th, and 31st, 2018, only consisted of 37 students.

The pre- and post-tests, which were designed by the Onebillion software publishing company, consisted of 50 questions that were administered in 15 minute sessions over a three-day period. Most students only required two sessions to complete the test, but testing was conducted in shorter sessions as needed. Pre- and post-testing was conducted individually with each child in the hallway next to their kindergarten classroom. The adults responsible for administering the tests refrained from identifying or correcting wrong answers; instead, their interactions with the students were restricted to encouraging them to answer the questions to the best of their ability and telling them they were doing a good job.

The 50 questions on the pre-test and post-test reflected the range of numeracy skills that students are expected to learn in kindergarten. Furthermore, the tests focused on different measures of early years mathematical ability, including language concepts and terms specific to mathematics (e.g., ‘more’ or ‘less’, ‘take away’, ‘fewer’, and ‘near’). For example, one question that focused on the language-based components of early mathematics asked the student to identify “Which cup has the most water?” (Purpura et al., 2017). Other measures included: sorting and matching; counting (to 3, 5, 7, 10, etc.); comparing items; recognizing different sizes, line lengths, patterns, and shapes; and manipulating numbers through simple addition and subtraction. The students received 1 point for each correct answer to a maximum of 50 points.

The experimental group consisted of 19 students taken from two half-day kindergarten classrooms (a morning class and an afternoon class). Another 18 students in the other two half-day kindergarten classrooms (the control group) received regular math instruction over the same 7-week period. With their classroom teacher’s supervision, guidance, and encouragement, the experimental group students practised math concepts using the Onebillion app, which had been uploaded to individually-assigned iPads, for 15-20 minutes each school day over a seven-week period between April 6th and May 24th. Onebillion’s math software developed for 3-5 years of age was deemed appropriate to these students’ developmental capacities. In addition to administering the tablet-based intervention and keeping track of each student’s daily use, the teacher also recorded attendance during the experimental period using a register provided in the Onebillion package of materials and maintained a star chart that indicated how many modules each student had completed. Since the math app is able to keep track of the topic that the child was working on, they were able to pick up where they left off each day. At the end of the 7-week period, the students in both groups were given a post-test in three 15 minute sessions over a 3-day period or in shorter sessions as needed. The evaluator administered the test at the school, and she received the assistance of the same Learning Support Teacher and volunteer research assistant.
To supplement the researchers’ findings, they compared the results of the assessment tools in the tablet-based math intervention to the Learning Pathway divisional math assessments conducted in November, February, and June of 2018 for each student in both groups (see Table A-1 in the Appendix).

Although the research design was experimental and quantitatively focused, the evaluator also conducted qualitative interviews with the experimental group’s classroom teacher and the school’s Vice-Principal. In addition, the parental consent form asked parents or guardians if they would be interested in participating in a 15-minute interview with the evaluator, either by telephone or in-person at the school. All parents declined to participate, however.

Materials Developed: N/A

Project Model

(see Appendix A). The project model is a screenshot from the math apps.

Logic Model Used for the Project

	Planned Work
Inputs: Resources Human & Financial	Staff resources: Principal, Vice-Principal, 3 Kindergarten teachers, a Learning Support Teacher, information technology staff to configure the iPads and upload math app software to iPads, volunteer assistant to administer pre- and post-tests. Other inputs include: supplies and printed materials, 20 iPads, Onebillion math software, school infrastructure required to deliver the program, such as classroom space, desks, and chairs. Funding for the acquisition of 20 iPads from the Chipman Family Foundation at the Winnipeg Foundation.
Strategies/Major Activities	Daily lessons in mathematics using the Onebillion software, which emphasizes a number of different measures of early years mathematical ability, such as: sorting and matching; counting (to 3, 5, 7, 10 etc.); comparing items; recognizing different sizes, line lengths, patterns, and shapes; and simple addition and subtraction; Kindergarten students in the experimental group use the math app for 20 minutes per school day over a period of seven weeks.
	Intended Results
Outputs	Immediate countable results/performance indicators 39 students participate in a pre-test and post-test; 19 students use the math app for 15-20 minutes each school day over a 7-week period; student attendance rate; number of stars/certificates awarded to each student.
	Outcomes (related to the objectives/mission of the program)
Short-Term Outcomes	students learn numeracy skills that prepare them for Grade 1 in terms of meeting the Learning Pathway divisional requirements; Opportunities are provided for students to catch-up on missed or misunderstood math lessons from the previous school year; The math software stimulates student interest in math and optimizes their learning experience; students improve their fine and gross motor skills; students become confident and proud learners; students learn independence; students develop a positive outlook about school and learning new skills; students are comfortable practising math using the tablet-based technology; school attendance rates improve.
Intermediate Term Outcomes	Students develop math competence and confidence as evidenced by improved math marks in the primary school years; Students are more engaged in their academic studies/schooling; School attendance rates improve; Improve academic standards and outcomes in the early years; Student curiosity about academics in general or other subject-matter (e.g. reading/writing) is nurtured.

Ultimate Goals or Impact	Long-term (the student's educational and life outcomes) The experimental group students' math skills exceed those of age-matched peers throughout their years of schooling; The program generates resilient children who have a high probability of reaching their academic potential in elementary school and performing at or above grade level; Positive spillover effects are passed on to siblings and other family members and other social networks; Reduced school push-out/drop-out rates: participants graduate from high school and have opportunities to pursue higher education; Students exhibit a desire for lifelong learning; Improved math literacy and educational outcomes of Indigenous people in the high poverty areas of Winnipeg. Social impacts: community capacity/social capital expands in high-poverty areas of Winnipeg.

Performance Indicators and Measures

The researchers determined that the most meaningful way to measure the success of this intervention would be to utilize an experimental design consisting of an experimental group (i.e., the students who used the Onebillion math app) and a control group (i.e., the students who received standard face-to-face instruction). This task was accomplished with a group of 37 kindergarten students at David Livingstone Community School in the Winnipeg School Division.

The researchers adopted a number of performance indicators in examining the pre-test and post-test scores, including:

- Change in the average scores of all students in each group from pre-test to post-test.
- A comparison of statistically significant differences between the scores of the experimental and control groups.
- Statistically significant differences between the two groups at the pre-test stage. For example, if the experimental group is already strong in math, they may progress at a faster rate than the control group.
- Comparison of average score differences between pre-test and post-test for high and low performers in both groups.
- Gender and age (born earlier versus later in the year) comparisons in average performance.
- Differences between the morning and afternoon classes for both groups.

- The role that attendance rate may have played in the results for the experimental group.
- In the experimental group, the correlation between post-test scores and stars/certificates earned after completing each of the ten modules.
- Exploring potential links between the Learning Pathway divisional assessments and the learning outcomes of the control and experimental groups.

If statistically significant differences between the experimental and control groups are observed for a number of these performance measures, it becomes possible to tentatively attribute these positive academic outcomes to the Onebillion math app. Although the researchers anticipated positive outcomes, the present study explored whether a shorter intervention of seven weeks could result in significant improvements in math competencies in the experimental group. The researchers hypothesized that they would observe small improvements in the control group; however, as indicated in the logic model, the end measure of academic success will be whether or not there is a significant improvement in high school completion rates and subsequent enrollment in post-secondary studies. Unfortunately, this data will not be available for many years to come. Similarly, the sustainability of student learning as they enter grade one will remain unknown unless a longitudinal study is undertaken.

As a final data-collection measure, the researchers invited the experimental group's kindergarten teacher and administrators at David Livingstone Community School to participate in semi-structured interviews at the end of the program. The objective of these interviews was to gain insight into the student/teacher experiences with the tabled-based math intervention. The interviews consisted of seven groupings of specific questions, although the researchers encouraged participants to deviate outside of this line of questioning if they preferred. Each interview took approximately 30 minutes to complete, and each interviewee's observations were analyzed and recorded qualitatively in order to further support our quantitative findings.

Evaluation

Evaluation Framework: Planned Data Collection

The evaluator participated in an initial telephone conference call with the Nurturing Capacity Program Coordinator from Indspire, the Director of the Chipman Family Foundation, and the Administrators and Teachers at David Livingstone Community School. During this meeting, it was decided that the best way to accomplish this evaluation was by utilizing an experimental design. In addition, a number of necessary modifications were identified. For example, nursery students would be excluded because they were not academically prepared to participate, the wording of the tests was identified as being in need of further refinement in order to address cultural and language issues, and the random assignment of students to the experimental and control groups was deemed impractical.

On November 6th, 2017, an in-person meeting was scheduled between the evaluator and key stakeholders at the school. The agenda included a review of the parent/guardian consent form, a discussion of the wording in the student assessments (pre-test and post-test), and whether the Learning Pathway divisional assessments would be available for comparison with the results of the experimental study. In addition, the researchers reviewed the request for project approval that was subsequently submitted to the Winnipeg School Division, and they also discussed a list of potential school stakeholders and other individuals (e.g. parents or guardians) who might be interviewed for the qualitative component of the evaluation.

Student assessments were initially scheduled for late January and mid-March, although the timeline was later revised to early April and late May. The data collection sources are listed in Table 2.

Table 2: Sources of Actual Data Collection

Name/number	Position/Role	Methods
19 students in the morning and afternoon classes in Room 20 Girls: 9; Boys: 10	Kindergarten students	Quantitative analysis: Experimental Group
20 students in the morning and afternoon classes in Room 21 Girls: 13; Boys: 7 (2 girls left the study prior to the post-test)	Kindergarten students	Quantitative analysis: Control Group
Ms. Pedersen	Room 20 Teacher	Qualitative interview with homeroom teacher of the Experimental Group
Ms. Mainville	Vice-Principal	Qualitative interview
Mr. Millican	Project initiator	Email correspondence and in-person communication regarding the Onebillion math app and history of the project, i.e. the decision to pilot test the Onebillion math app in Winnipeg.

Qualitative interview questions were designed to collect data on what worked well in the tablet-based intervention, how well the students responded, and whether this technology built on the strengths of the provincial math curriculum. Furthermore, the researchers were also interested to find out what challenges were encountered, what lessons were learned, and which causal factors contributed to the program's successes.

The concept behind the experimental design in Table 3 is that daily individualized practice at a pace dictated by the student over a seven-week period would cause the experimental group to realize greater gains than the control group with respect to math competency.

Table 3: Experimental Design

Kindergarten Students' Assigned #	**Pre-test (1) 3-15 minute sessions**	**Experimental Group Uses the tablet-based math app 15-20 minutes each weekday**	**Post-test (1) 3-15 minute sessions**
Experimental Group	April 2, 3, & 6, 2018 All Students	From April 6-May 24, 2018 19 students use math app	May 24, 29 & 31 All Students
1.	X	X – Math tablet APP for 3-5 year olds	X
2.	X	X – Math tablet APP for 3-5 year olds	X
3.	X	X – Math tablet APP for 3-5 year olds	X
…	X	X – Math tablet APP for 3-5 year olds	X
19.	X	X – Math tablet APP for 3-5 year olds	X
Control Group			
20.	X	Standard pedagogical instruction	X
21.	X	Standard pedagogical instruction	X
22.	X	Standard pedagogical instruction	X
…	X	Standard pedagogical instruction	X
37.	X	Standard pedagogical instruction	X
(1) Using the assessment tool provide by the Onebillion organization			

Evaluation Outcomes: Summary of Key Findings

Descriptive analyses are listed in Table 4. None of the pre-test scores in the experimental group were statistically different from those of the control group. However, the statistically significant differences in the post-test scores between the two groups are particularly noteworthy. Scores that are statistically different simply indicate that there is a reasonable degree of certainty that the observed difference is reliable and probably true. Since the pre-test scores were relatively similar in value, the difference between these scores had a higher probability of not being a true difference.

Collectively, the findings in the current study support prior research. The quantitative outcomes in Table 4 were correlated with the teacher’s assessment of student engagement with the math app. An interview with the homeroom teacher revealed that the students were excited to use the iPad and, as expected, they were more likely to engage in a task that they perceive to be fun and easy. Furthermore, the individualized instruction helped them to stay on task and to become more independent learners. Therefore, at least in part, this intervention appeared to lay the groundwork for the development of a more internalized individual interest in learning. The teacher remarked that the tablet-based technology was relatively easy to supervise, which is consistent with the findings of a prior study (Stacy et al., 2017).

Table 4: Comparisons of Experimental and Control Group Results

Experimental Group	**N=**	**%**	**Post-test**	**Pre-test**	**% change**	**Cohen's d**
			Average test scores			
Average score (out of 50 points)	19	100.0	33.9*	26.0	+30.4%	0.99
Students scoring higher in the post-test compared to the pre-test	19	100.0	-	-	-	
Average score of students scoring 50% or lower correct answers on the pre-test	11	57.9	29.6*	19.8	+49.5%	1.75
Average score of students scoring over 50% correct answers on the pre-test	8	42.1	39.8*	34.5	+15.4%	1.31
Control Group	**N=**	**%**	**Post-test**	**Pre-test**	**% change**	**Cohen's d**
			Average test scores			
Average score (out of 50 points)	18	100.0	25.7	23.3	+10.3%	0.35
Students scoring higher in the post-test compared to pre-test	11	61.1	-	-	-	
Students scoring lower on the post-test compared to the pre-test	4	22.2	-	-	-	
Students scoring the same on pre-and-post-test	3	16.7	-	-	-	
Average score of students scoring 50% or lower correct answers on the pre-test	10	55.6	21.4	18.2	+17.6%	0.61
Average score of students scoring over 50% correct answers on the pre-test	8	44.4	31.1	29.8	+4.4%	0.52

Note: students were granted one point for each correct answer on the pre-test and post-test.
*statistically significant difference with respect to the control group ($p<.05$).
Cohen effect sizes tell us something about the strength or magnitude of the difference between the pre-test and post-test. The larger the effect size, the larger the strength of the significance test. The within-group effect sizes from pre-test to post-test were large for the experimental group (Cohen's d=0.99) and small for the control group (Cohen's d=0.35). Cohen's effect sizes are considered small if d=.20; medium if d=.50 and large if d =.8 or greater (Cohen, 1988).

Regarding improvements in the performance of experimental group students facing language-based challenges (EAL, speech, and other issues, etc.), the teacher concurred that the math app was able to mitigate the language-related gaps in math instruction, as certain aspects of the app (visual, etc.) did not necessarily require strong language skills. As such, the reduced emphasis on language makes the app an effective tool that could be used to help EAL students keep pace with, or catch up to, their English-as-a-first-language peers.

Highlights of Findings

- This research highlights selective improvements in a few areas. As expected, the experimental group showed a greater overall % change than the control group in average score from the pre-test to the post-test at +30.4% compared to +10.3%, respectively.
- Notably, the experimental group scored only slightly higher than the control group in the pre-test (2.7 points higher average points or 11.6%) and considerably higher in the post-test (8.2 points, or 31.9%, higher than the control group's average score).
- The students who benefited most from using the Onebillion math app were those in the experimental group who had weaker scores in the pre-test (a score of 50% or lower). These students' post-test scores far exceeded expectations, increasing by an average of 49.5% (range: 12.5-154.5%). In fact, these students performed better than the stronger students (pre-test scores exceeding 50%), who only achieved an average increase of 15.4% on the post-test (range: 2.4-33.3%). In addition, the teacher remarked that the app improved the math-challenged students' attention span and listening skills, as it forced them to slow down and listen carefully to instructions. As a result, the students displayed less overall distraction than with the usual pedagogical practice. In particular, students with learning challenges (e.g. EAL, speech difficulties, or other issues) achieved the strongest results, which was remarkable considering they had only been practicing with the app for seven weeks. However, this finding may partly reflect their improved language abilities over that period of time.
- The improvements were not as significant in the control group. Here again, the biggest gain was experienced by students who had weaker scores in the pre-test (50% or lower). These students' post-test scores increased by an average of 17.6% compared to only 4.4% for the stronger students in control group (50% or higher in the pre-test). These findings are not wholly surprising, as a certain amount of learning and growth in math competency was expected for the students receiving standard face-to-face instruction.
- While the researchers found a small and insignificant correlation between school attendance rates and post-test scores in the experimental group, they also found a statistically significant positive correlation (Pearson's correlation coefficient

0.48, $p < .05$)[2] between post-test scores and the number of stars awarded to the student (i.e. a star indicates that the student has completed a module). The homeroom teacher also noted that the stars/certificates were effective in motivating the students.

- There were no major differences in average scores between the morning and afternoon classes in the experimental group (pre-test: 0.8 points higher average in the morning class; post-test: 1.7 points higher in the afternoon class). Conversely, the average score in the control group morning class was higher in both the pre-test and post-test (pre-test: 5.5 points higher; post-test: 3.0 points higher). None of the differences reached statistical significance, and thus would not have affected the study results.
- Some gender differences were also observed. The girls in the experimental group outperformed the boys in both tests (pre-test: 5.3 points higher; post-test: 2.7 points higher). However, the gap between the boys and girls narrowed after the post-test, which suggests that the boys made significant learning gains from practicing with the math app. Similarly, the girls in the control group also outperformed their male counterparts in both tests (pre-test: 5.3 points higher; post-test: 5.9 points higher), but, unlike the experimental group, the gap did not close following the post-test.
- With the exception of one student born in 2011, the year of birth for all students was 2012. The findings showed little advantage for experimental group students born earlier in the year (January to May) compared to those born later in the year (June to December). The children in the experimental group born between January and May scored 1.3 points higher on the pre-test and 4.0 points higher on the post-test; however, neither of these differences were statistically significant. Conversely, the differences in the control group were large and statistically significant, favouring students born between January and May (pre-test: 8 points higher on average; post-test 7.9 points higher on average). Since the average scores were consistent from pre –to-post-test, these differences would not have affected the study results.
- The two groups scored comparably on the individual pre-test questions, as the control group's average score on 35 of the 50 questions fell within 5 points of the experimental group's average score. Of the 15 questions that fell outside this range, only 2 were statistically different in favour of the experimental group: positional words and number recognition. However, in the post-test, the control group's average score only fell within 5 points of the experimental group's average on 19 of 50 questions. This change was largely due to the substantive improvements made by the students in the experimental group between the pre-test and the post-test. In the post-test, the differences between the two groups

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[2] Pearson's correlation is a measure of the strength and direction (in this case, a positive relationship) between two variables: number of stars awarded to a student and their post-test scores. An estimate of 0.48 is deemed a medium-to-large strength of the correlation.

reached statistical significance in 15 out 50 (30%) questions, once again largely due to the experimental group pulling ahead in terms of learning gains.

The experimental group showed major improvements over the control group in the areas of pattern recognition (e.g. triangle, triangle, rectangle); early pre-proportional reasoning (same as, more than, fewer than); basic arithmetical learning (one more/one less than; two less than); basic arithmetic visualization (e.g. I have 8 cats and take away 3); number recognition and counting to 20; and telling time on an analogue clock.

The Pathway Learning Assessment analysis completed by the evaluator (see Table A-1) indicated that the experimental group was the stronger of the two groups, as many of them had already reached the kindergarten achievement expectations outlined in the divisional curriculum framework prior to the implementation of the Onebillion pilot project. By June of 2018, 17 out of 18 control group students were missing at least one curricular target (compared to 8 out of 19 in the experimental group). Furthermore, at least 50% of the control group had not achieved the requirements in one or more of six areas, including: mathematical and flexible thinking, pre-proportional reasoning, rote counting, place value, and basic arithmetic learning. Similarly, the majority of students (6 out of 8) in the experimental group who did not reach all of the kindergarten curricular targets had earned 5 or fewer Onebillion stars. As shown in Table A-1, the math app seemed to help a minority of experimental group students improve in the area of rote counting and place value (5 out of 19).

The analysis in Table A-2 is consistent with findings in the Pathway Learning Assessment. While the control group improved in areas mostly related to the kindergarten math curriculum (e.g. counting to ten; size attributes, number recognition, etc.), Onebillion program was particularly beneficial for the students in the experimental group because it challenged them to perform above their grade level in a variety of areas, including: comprehension of positional words, such as left, right, and middle; counting and basic arithmetical learning, e.g. two less than 5; arithmetical visualization (end of Grade 1), e.g. I have 4 fish and I add 4 more. How many fish do I have?; equal sharing, e.g. I have 6 candies, so how do I share them equally between 2 children?; and skip counting, ordinal numbers, and telling time on an analogue clock. Given their significant gains, it is likely that these students will enter Grade 1 with confidence in their mathematical skills.

The above results suggest that the Onebillion math app likely contributed to improvements in the math scores of the experimental group students, particularly males, students with weaker pre-test scores, and those earning more stars by completing the modules. This conclusion was supported by the homeroom teacher, who confirmed that overall student interest in solving math problems and general performance in math had both improved during the study.

For readers who are adept in statistical analysis, the researchers report Cohen's *d* within-group effect sizes in Table A-3, which compares pre-test and post-test average scores in the experimental and control groups on the basis of gender, morning and afternoon class, and born earlier/later in the year. Effect size indicates something about the magnitude or strength of the difference between the pre-test and post-test. The differences were large in all categories for the experimental group, indicating substantive increases in average scores, and small-to-medium for the control group.

Study Limitations

Despite this study's remarkably positive results, the approaches that were used have several limitations that warrant discussion. For instance, other studies that have assessed tablet-based math apps employed more sophisticated research designs and analytical approaches, particularly the use of multivariate analyses (i.e. the statistical analysis of many variables at once, which usually requires large data sets). In contrast to prior studies (see Pitchford, 2015; Outhwaite et al., 2017), this was a pilot project with a relatively small sample size; as such, the sample used in this study may have been too small for accurate analyses, and it was certainly too small to obtain detailed statistical analyses. In terms of practicality, since accessibility was a critically important consideration in preparing this evaluation report, more complex multivariate analyses were deliberately avoided.

Furthermore, the random assignment of students to the experimental and control groups was deemed impractical in the study's early planning stages; as an alternative option, it was decided that students would be assigned to their respective groups based on their enrollment in a classroom. As shown in Table A-1, compared to the control group, most students in the experimental group had already achieved the kindergarten math requirements at the pre-test stage. The control group class might have benefitted more from practicing math using the app. It is also possible that the results were influenced by the 'test-taking effect', which is when knowledge of the pre-test influences scores on the post-test (i.e. students remember content from the pre-test). In evaluation, this is referred to an internal validity problem, as it affects the observed outcome. In addition, the evidence for the pre- and post-test's statistical reliability as a tool or valid measure remains unavailable. These may all be different explanations for the positive results.

Nevertheless, even though the researchers were unable to conduct a large-scale study of the causal links between app use and improved math ability, this study provides an important first step in testing the practical utility of tablet-based math apps in kindergarten classes. Indeed, at a time when diversity and inclusive learning needs are rapidly increasing in classrooms, the Onebillion math app offers the Winnipeg School Division a promising avenue for future early years math interventions.

Outcomes: Most Significant Accomplishments and Lessons Learned

In terms of academic accomplishments, the present research provides initial evidence that the Onebillion tablet-based intervention could be an effective strategy for improving kindergarteners' math readiness when they begin elementary school. In addition, the results of this study also suggest that the use of other types of apps (e.g. literacy apps) may also hold great potential for increasing student engagement in a broader range of educational activities. These findings are in line with those of other research studies noted earlier. Nonetheless, the most significant outcome of this study was the huge improvement in learning and test performance made by students in the experimental group who struggled on the pre-test (a score of 50% or lower) despite the relatively short seven-week span between the pre- and post-test. These results exceeded expectations by far, and they are consistent with other research that reported substantial learning improvements in students who struggle in math (Outhwaite et al., 2017). Moreover, tablet-based technologies can also be useful in addressing the gaps in the educational experience of EAL students who struggle with language-based skills. Equally as important, tablet-based math apps tend to elicit enjoyment and increased motivation in students; this is a highly significant outcome, as students who view learning as an enjoyable activity will likely be more motivated to engage in it and experience better future educational outcomes.

Although this study yielded some very encouraging results, there remain areas for improvement. One such area was the app's lack of a reporting tool that would allow the teacher to keep track of each student's progress. In other interventions, the app provides the teacher with a dashboard that indicates if a student is using inefficient strategies to solve math problems. This would be a beneficial addition to the present intervention, as it was unclear at times whether a student was guessing the answer or using a clear strategy. Furthermore, a dashboard tool would enable the teacher to dedicate more time to working with students who are having learning difficulties and to redirect their attention to more efficient strategies for solving math problems. In addition, seven weeks was far too short a time period to complete all 10 modules for some students, as only 6 out of 19 students were awarded all 10 stars or certificates.

Furthermore, it took more time than initially anticipated to get the school division's approval to acquire and image the iPads, install the licenses, upload the Onebillion app to the server, incorporate Winnipeg School Division's mandated security features, and configure the tablets (e.g. Wi-Fi and sign-in features). Therefore, other schools contemplating a similar pilot project should allow no less than three months for the developmental aspects of the program prior to administering the pre-test. Notably, it also takes time to prepare the kindergarten students to handle the iPads, for instance, developing skills in the appropriate use of the iPads and setting ground rules for the proper removal and storage of the tablets. In addition to getting the hardware and software requirements in place, the school also had to purchase protective stand cover cases to safeguard the tablets.

Next Steps for the Project

The current evaluation is a first step in assessing the feasibility of tablet-based math practice as a way of improving math readiness in kindergarten students and bringing additional high-quality supports to every student in Winnipeg’s low-income areas. Onebillion is a carefully designed mathematics program that aims to address cumulative learning processes and to improve the accessibility of the subject matter for early years students. Therefore, due to its focus on the foundational aspects of mathematics, the math app is particularly helpful for students who are struggling with the subject matter in the provincial curriculum framework. The app makes math accessible to students by breaking down problems into small manageable steps, providing them with ample opportunity to practice and master the skills in each module, and providing them with positive feedback when they correctly solve a problem or finish a level. This is quite an innovation compared to normal pedagogical practices wherein feedback to individual students is often delayed and individual attention is at times lacking (Pitchford, 2015).

Regarding next steps, the school’s Vice-Principal noted that the faculty and administration intend to be proactive in targeting K-3 math instruction, as this area needs to be strengthened at the school**.** Currently, the tablets are being shared with the control group classroom so they can also practice their skills using the app. In the 2018-19 academic session, the school plans to have the new group of kindergarten students practice math using the tablets beginning in September or as early as possible. As in the pilot test, students using the tablets will practice on them of for 15-20 minutes per day. Finally, the school will consider the feasibility of tracking this year’s experimental group students through to Grade 1 to assess whether improvements are sustained over time, although summer learning loss may be a factor to consider.

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APPENDIX A: PROJECT MODEL

MODULES COVERED IN THE ONEBILLION MATH CURRICULUM APP

Topics covered

1	Sorting and matching
2	Counting to 3
3	Lines and patterns
4	Counting 4 to 6
5	Where is it?
6	Counting 7 to 10
7	Patterns and shapes
8	Counting 1 to 10
9	Comparing
10	Adding and taking away

There are 10 modules and each one has a number of tasks based on the topic covered, as well as quizzes to evaluate learning. Students are incentivized to earn stars and certificates by completing the quizzes with 100% accuracy at the end of each module (see https://onebillion.org/)

Table A-1: Number of Students Who Reached Curricular Targets in the Learning Pathway Divisional Assessments

Experimental Group, total=19 students [Control Group, total = 18 students]	Target completed in the June, 2018 Assessment (after the Onebillion intervention)	Target completed prior to the Onebillion pre-test (by February, 2018)	Curricular target not yet achieved in June, 2018
	# of students who achieved curricular targets [Control group]		
Pre-counter: Modeling and communication mathematical thinking	1 [5]	18 [12]	0 [1]
Application of knowledge (making sets by matching to 5 and to 10)	1 [6]	18 [12]	0 [0]
Knowledge (rote counting to 5 and to 10; subitizing familiar dot patterns to 3)	1 [2]	18 [12]	0 [4]
Modeling and communicating mathematical thinking (manipulatives to describe a numeral in two parts [to 5] and to 10, constructing sets of objects, and repeating patterns)	2 [3]	13 [2]	4 [13]
Application of knowledge:			
Flexible thinking (counting objects: how many in a set or comparing two sets [to 5] up to 10)	3 [2]	15 [7]	1 [9]
Pre-proportional reasoning (using manipulatives to compare quantities: same as, more than, fewer)	3 [2]	15 [6]	1 [10]
Knowledge:			
Rote counting (forward to 20…to 30; backward from 10; say number before/after any given number to 10)	5 [5]	9 [2]	5 [11]
Place value (subitize familiar patterns to 5…to 6 on dice, on five frames, using finger patterns)	5 [2]	8 [4]	6 [12]
Basic arithmetic learning (name one more/one less to 5)	2 [6]	15 [3]	2 [9]
Algebraic reasoning (creating a repeating pattern with manipulatives, sounds, or actions)	2 [6]	16 [6]	1 [6]

Table A-2: Experimental and Control Groups: Areas of Math Skills Improvements from Pre-test to Post-Test, as Determined by Cohen's d Size Effects

Type of Question	Examples	Experimental Group	Control Group
	X = Cohen's *d* > 0.49 (a medium-to-large size effect in the difference in average score from pre –to-post-test)		
Size attributes	Which circle is odd one out	(1)	X
Recognizing, differentiating, counting	Recognizing and counting 5 frogs	(1)	X
Shape recognition	Find the circle and rectangle	X	-
Counting to 10	Which box has 6 strawberries	(1)	X
Positional words	Which child is in front of/behind fence	(1)	X
Subitizing	Counting dots on a domino	X	X
Size attributes	Odd one out; matching monkeys	X	X
Rote counting (to 10)	Count # of pigs	X	-
Basic arithmetic learning (kindergarten level)	1 more than 7	X	-
Pre-proportional reasoning	Same as, more than, fewer than	X	-
Pre-proportional reasoning – Grade 1	Equal sharing; 2 plates and 6 cup cakes	X	-
Basic arithmetic visualization- Grade 1	I have 8 cats and take away 3	X	-
Symmetry	Halving a circle	X	X
Counting – Grade 1	Counting 15 pencils; drawing 14 apples on a tree	X	-
Number recognition	Number 18	(1)	X
Number recognition to 20 – Grade 1	One more than 19	X	-
Number recognition to 20 – Grade 1	Circle 10, 16, 19	X	-
Telling time on an analogue clock	e.g. 9 o'clock	X	X
Sequencing	Steps to grow a tree	(1)	X
(1) Small/minimal size effects, as the group had achieved a high (and/or similar) score in both the pre –and-post-test.			

Table A-3: Cross-Tabulations of Pre-Test and Post-Test Average Scores by Gender, Age, and Classroom

	Average Test Scores			
Experimental Group	Post-test	Pre-test	Difference	Cohen's *d*
Girls	35.3*	28.8	6.5	0.77
Boys	32.6*	23.5	9.1	1.33
Morning class	33.0*	26.4	6.6	0.93
Afternoon class	34.7*	25.6	9.1	1.05
Born earlier in the year (January-May) (1)	35.8*	26.6	9.2	1.12
Born later in the year (June-December) (1)	31.8*	25.3	6.5	0.87
Control Group				
Girls	28.0*	25.4	2.6	0.40
Boys	22.1	20.1	2.0	0.34
Morning class	27.4	26.4	1.0	0.23
Afternoon class	24.4*	20.9	3.5	0.45
Born earlier in the year (January-May) (1)	31.0	28.7	2.3	0.67
Born later in the year (June-December) (1)	23.1	20.7	2.4	0.37

(1) Note: all students were born in 2012, with the exception of one student in 2011;
*Statistically significant difference with respect to the pre-test score, $p<.05$;
There were no statistically significant differences in pre- and-post-test scores for the experimental group regarding girls compared to boys, morning versus afternoon classes, or students born earlier or later in the year.
In the control group, the only between-group difference that reached significance was students born earlier compared to later in the year for both pre –and-post-test, $p<.01$. We found an 8-point difference in both tests in the control group.