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A STUDY OF THE EFFECTIVENESS OF IXL MATH ONLINE SOFTWARE ON STUDENT ACHIEVEMENT IN AN URBAN MIDDLE SCHOOL

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ABSTRACT

A STUDY OF THE EFFECTIVENESS OF IXL MATH ONLINE SOFTWARE ON STUDENT ACHIEVEMENT IN AN URBAN MIDDLE SCHOOL

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The purpose of this study is to evaluate the effectiveness of IXL Math online software in raising student achievement on the New York State Math exam, with special focus on effects by student gender, ethnicity and disability status. The study includes an analysis of the relationship between scale scores and IXL time spent using the system, number of problems attempted, and skills mastered. This study is significant because national, state and local measures indicate no measurable improvement in math achievement with an alarming percentage of students scoring below proficient levels. Further, past studies examined teacher perception or student motivation regarding educational technology and achievement. To date, is the only study independently analyzing the effectiveness of a widely-used online learning application, IXL Math, in a Title 1 urban Middle School consisting of 6th, 7th and 8th grade students and measuring the impact of the online program on students most at-risk, and whose attributes comprise the lowest third percentile of achievers.

A quasi-experimental research design was conducted by comparing two distinct cohorts of students – one using traditional paper assignments and the other completing IXL online assignments, and using statistical analysis, a determination was made that there was no significant difference in the scale scores between the two groups. Additionally, the interaction between IXL and gender, ethnicity, and disability, and its effect on math scores was analyzed. Two-way analysis of variance tests and Pearson's correlation were conducted using SPSS software package. The major findings are discussed offering recommendations for future practice and research.

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CHAPTER 1

Introduction

National and international comparisons of US students' performance in mathematics have indicated that there has been little improvement in mathematics performance over the past decade, which remain at approximately 34% of 8th graders attaining Proficiency or higher scores, and the US remains at or slightly below average in international comparisons (National Center for Educational Statistics, 2018). Educational policy makers have supported various initiatives to improve overall mathematics achievement of students, including curriculum modifications, changes in standards and goals, changes in assessment formats, and instructional initiatives. Among the latter have been various technology-based approaches for reinforcing concepts as well as teaching new ones. Commercial companies have developed software and online modules for mathematics skill development, and these approaches have been widely purchased by school districts.

The National Center for Education Statistics reports that 89% of American households have computers and 82% have Internet access (NCES, 2016). Given the ubiquitous nature of the internet and that more students have computer and Internet access, many enterprising companies have created educational programs and applications. Educational programs such as Khan Academy, IXL, Castle Learning, Google Classroom and many others may offer white papers and research studies about how well their program works but do they really deliver on their promises? More importantly, do they perform the necessary work that is intended by the pedagogical goal and content knowledge and skill needs, and to improve student outcomes?

The United States is estimated to spend $14 Billion on K-12 educational technology (GovTech, 2018). Districts and schools spend enormous amount of money on these programs but are they ever validated by school districts and schools relative to their effectiveness? Educators may rely on the claims of vendors and not do their own research as to what works for their school setting. Since so many educational technology products are available, it is increasingly more important for educators and administrators to become discerning users of online educational products (Picha, 2018). They must select the application or online program that best fits the educational goal. But it cannot stop there. Once implemented, the program must be evaluated for effectiveness. That is, was the intended result of increasing student achievement realized by the technology?

Among the various software and online learning packages in the market is the IXL online program. IXL Learning's Research Department published 12 state-wide studies concluding that "using IXL outperforms schools using any other program or method" (IXL Learning, 2018). Further, IXL published a report, "The IXL Effect" regarding how well students achieve in schools using their online application vis-vis students in schools without IXL (IXL Learning, 2018). Some of the research is briefly summarized in Chapter 2. The present study provides an independent evaluation of the outcomes of the IXL program at a site where there has been implementation for 2 years.

The overall question for this study is: Is the IXL Math online program working to increase student achievement for all? Does it improve the mathematical skill level of every learner, especially those most at-risk? This study may serve as a model for teachers and administrators to evaluate the effectiveness of IXL and similar programs in their schools. It will also provide guidance for school administrators on points of consideration when selecting programs for widespread use in their districts.

Purpose of the Present Study

The purpose of this research study is threefold. The first is to determine if IXL Math has a positive effect in significantly increasing student achievement on NYS Math exam in a Title 1 urban Middle School. The second purpose is to examine if IXL Math has a positive effective in significantly increasing student achievement on NYS Math exam for subgroups of students regarding their gender, ethnicity and learning disability status; each contributing a characteristic that comprises the "Lowest Third." The third purpose is to find if a relationship exists between IXL usage, the number of questions completed, and the number of standards mastered and the scale score achievement on the NYS math assessment.

Performance outcomes from students using IXL math. Regarding the first purpose relative to evaluating IXL Math's effectiveness on student achievement, there is little independent research conducted by an individual school or district. This researcher found very few studies analyzing IXL's impact on student achievement. However, IXL Learning conducts its own studies where its research department published 12 state-wide studies concluding that "using IXL outperforms schools using any other program or method" (IXL Learning, 2018). Further, IXL published a report, "The IXL Effect" regarding how well students achieve in schools using their online application vis-vis students in schools without IXL.

Hollands and Pan (2018) evaluated IXL and eSpark as digital math tools for 9,000 students in the northeast United States. A regression analysis of student achievement on

Star Math assessment demonstrated no significant increase in gains with IXL. The authors discussed that IXL is helpful in practicing math skills but not as much in "applying concepts to complex, multi-step problem." Additionally, Longnecker (2013) conducted a study of male and female middle school students of diverse backgrounds and abilities consisting of 6^{th}, 7^{th} and 8^{th} grade math students who attended an urban middle school in southern Davidson County, Tennessee. The study was quasi-experimental comparing a cohort of 1,101 IXL Math users (treatment group) in 2010-11 academic year with a retrospective cohort of 925 non-IXL Math users (control group) in 2009-10 academic year. An ANOVA test was used to find if any statistical significance in differences between the two groups in three instruments used to measure achievement. It was believed that with more practice time, the achievement scores for all middle school students would increase. The findings were surprising – the study found that there was no significant effect in increasing math achievement scores using IXL Math. In fact, where there was an effect, it produced a negative one demonstrated by a decline in student performance. The study highlighted that the traditional manner of instruction produced better student achievement. So, if educational technology is thought to bring about increased student achievement, is this result realized by the technology? Is the investment of purchasing a subscription to IXL Math justified? This study aims to evaluate whether IXL Math was effective in improving student scores attending an urban school on a New York State math assessment for all middle school students.

Performance outcomes of IXL math for subgroups. The second purpose is regarding the evaluation of IXL Math on student achievement with certain sub-group of students, namely: ethnicity, gender and learning disability. One research study examined the use of technology to increase the achievement levels of students of certain ethnicities, gender and socio-economic background. A casual-comparative study of ethnicity, gender and socio-economic status compared 149 pairs of 7th grade students (Clark, 2014). One control group in 2009 received traditional instruction and the treatment group in 2010 received computer-based instruction supplemental to the traditional instruction. Using one- and two-way ANOVA, the study concluded that there was no significant difference in math achievement scores between the genders on the state's standardized test – the math Criterion Referenced Competency test. With respect to ethnicity, there was a significant difference in achievement scores between Black and Hispanic students and White students, with the latter group performing better (Clark, 2014). Supporting the achievement of groups at-risk for school failure and dropout is a major concern in schools. It is imperative that evaluations of instructional approaches consider benefits to all students, not only those with previous educational advantages. The present study includes a sub-group analysis to investigate the impact on students who may be struggling with mathematics achievement related to previous experiences with learning.

Regarding students with learning disabilities in learning mathematics, in a mixed method study (McLeod, 2011) comprised of a quantitative analysis of 8th grade math scores in 67 districts in one state, and a qualitative analysis of interviews with 12 teachers concluded that "teachers believed that instructional technology is improving achievement with students with learning disabilities in mathematics" (McLeod, 2011). Interestingly, 100% of the respondents agreed with the central theme that "modern technology motivates students" (McLeod, 2011). Evidently, the use of technology can be a means to motivate students who are at-risk, however technology should be used to raise the achievement of all students regardless of background or ability. The second objective of this study is to determine if IXL Math can help to improve the achievement scores as measured on the New York State math exam of students of varied ethnicity, gender, and learning disability status.

Performance outcomes related to degree of IXL math usage. In connection with the third purpose of IXL Math usage and achievement scores, it seems reasonable that the more one uses educational technology, the greater skill development one would attain and thus the higher score one would achieve. Further, if students are more motivated by using technology, (McLeod, 2011) the likelihood they will practice more, and the result would be higher standardized test scores. When the relationship between IXL usage and students' math scores were examined (Longnecker, 2013), except for 7th grade students, no significant difference in test scores resulted. Perhaps the students experienced high utilization rates, but never increased their levels of proficiency or numbers of standards mastered; perhaps they stayed at the same level never mastering any or completed many problems below grade level. Yet, if there is a relationship between utilization rate and achievement levels, then educators should find ways to support increased usage rates by students of the online program to enhance their achievement. Therefore, the third purpose of this research study is to determine if a relationship exists between the scale score achievement on the NYS math assessment and the student's IXL usage, the number of questions completed, and the number of standards mastered.

Theoretical and Conceptual Framework

This study will blend together learning theory, teaching philosophy and best practices to provide guidance on using IXL Math educational technology: Zone of Proximal Development, Competency-based Learning, Differentiated Instruction, Personal Learning, and Data-Driven Decision-Making. The interaction of, and the complimentary way these elements work together in partnership to enhance the learning experience will be presented as a Conceptual Framework for this study in diagrammatic form. (See Figure 1.) The manner in which this study is informed by each of the learning theories is as follows.

Zone of proximal development. The zone of proximal development was developed by Lev Vygotsky, a psychologist and social constructivist. The zone of proximal development "refers to the difference between what a learner can do without help and what he or she can achieve with guidance and encouragement from a skilled partner" (McLeod, 2018). Since IXL is based on the mastery achievement of mathematics skills, the zone of proximal development (ZPD) is demonstrated when the level of questions a student can perform on his or her own without assistance from a teacher. As the student progresses in skill, the questions become increasingly more difficult. If the student answers incorrectly, the level drops and the questions become easier to match a student's skill level. The system provides solutions to the incorrect answer and students can diagnose their mistake before moving onto the next question hence building their knowledge and skill as they work towards mastery. Additionally, IXL Math provides "Recommendations" of various topics that students can self-select to complete based on a continuous diagnostic and the need to address skill deficiencies, or the added encouragement to try more challenging questions. Teacher knowledge of the software's capability and the zone of proximal development working together can aid in improving achievement of all students.

Competency-based learning. Competency-based learning is a method of education that allows students to progress through a curriculum at their own pace while they work towards mastery of content. The content is relevant to the individual learner and the pace of learning is customized to each student. Teachers must know the requisite skills students must process prior to mastering a skill, plan lessons and organize the content delivery, and assign practice topics on IXL Math that reflect those skills accordingly. The key to competency-based learning is the focus on mastery (TeachThought, 2018). Relative to IXL, students work at their own pace and on a question's difficulty level they can answer. When students have answered 10 questions in a row correctly, they move up in difficulty level. Once they have achieved 90% Smart Score, they enter the "Challenge Zone" and answer 10 questions correctly and achieve mastery. When a student answers incorrectly, IXL provides a written explanation of the correct solution, and if understood allows the student to proceed and progress. However, if the questions are too difficult, or the written explanations are not understood by the student, the IXL system will provide easier questions. While the system provides explanations for incorrect answers, no data is available as to whether or not students read the solutions. In either case, teachers may need to intervene, re-teach, and provide explanations to make the content accessible to the individual learner. This effort allows the student to build competency and to continue working towards mastery.

Differentiated instruction. What if every student, regardless of ability or background, had an Individualized Education Plan? Educators must identify how students are different and design a plan to support their learning. "Student differences matter, and effective teachers attend to those differences thoughtfully and proactively" (Tomlinson & Imbue, 2010, p. 1). Therefore, it is critical to know who students are so that educators can work with them to meet their needs where they are as learners. The true value of educational technology, and programs like IXL Math, is that they offer the ability to provide differentiated, individualized and personalized instruction (Basye, 2018). IXL helps educators to identify students who have achieved mastery and those who have not, and to offer enrichment or remediation assignments respectively. Teachers must reflect on the various levels of student mastery in one's classroom and adjust instruction accordingly to meet their needs (Poncy, Fontanelle & Skinner, 2013.) Students who are struggling may become discouraged and require greater teacher feedback than more accomplished students. The use of differentiation is the key to ensuring student success. Not only is technology useful in providing mathematical practice, but also provides the additional benefit of determining the learner's mastery. This is especially important for underserved students who typically struggle and require scaffolding provided by a teacher in order to progress academically.

The teaching philosophy of differentiated instruction informs this study because teachers must decide the best method of content delivery. It may not always be using an online program like IXL Math; it may be using a more traditional instructional method. IXL Math is designed to be an interactive worksheet offering unlimited practice of singular skills. It does not blend multiple skills together, nor does it offer multi-step problems. For this, teachers may need to incorporate traditional educational methods and provide more human interaction to supplement their technological efforts. Completing practice problems that are organized in a suitable way, and tailored to meet each student needs, have the capacity to increase academic performance (Stacey, et al., 2017). Therefore, educators must choose which topics students will learn, select the order in which they will learn them, the manner in which they will complete them, and identify any gaps in pre-requisite skills that may prevent students from achieving mastery. The IXL system makes it easy for teachers to identify and select topics based on grade, skill or strand.

Personalized learning. Personalized learning offers a tailor-made educational experience to address the individual needs of the learner. It is a student-centered approach that provides differentiated instruction and supports student outcomes based on mastery of the subject matter (Dreambox Learning, 2018). It is education that results from what students are doing as they manage their own learning (ISTE, 2018). Personalized Learning is composed of several points: Every learner should have an individual accounting of his or her abilities, likes, dislikes, styles and objectives, and should have a personalized educational route. The goal of one's education should be to attain expertise of the content, and to achieve such buy following a succession of progressively more difficult material. To achieve this end, school communities must be willing to bend and adapt to meet individual learner needs. (Herold, 2016.) IXL Math helps to achieve these goals in the following way: the online program features a continuous diagnostic that makes personalized assignment recommendations based on a students' mastery level. Using strand analysis, and based on students' individual levels, the system automatically assigns a personalized action plan for students to complete - either to strengthen their performance with skill on which they did not achieve mastery, or to challenge them with questions of a greater degree of difficulty. One of the advantages with technology with respect to personalized learning is the teacher can assist all students at the same time, while focusing on the needs on individual students or small groups (Pane, 2018).

Data-driven decision-making. Data-driven decision-making offers direction in terms of how schools can use management information systems in education focusing on new technologies and analysis to help guide student learning (Breiter & Light, 2006.) The Data-driven decision-making framework provides a means to improve student achievement by strategically using student data to measure growth in student achievement. Essentially the model "uses relevant and diagnostic data to inform instructional and operational decisions" (Gill, Coffee-Borden & Hallgren, 2014). This data can not only be used to determine student achievement but also whether the chosen software or online program positively contributed in the outcome, thus validating its selection. It is this process of validating the online program relative to increasing student achievement that is so important.

Data-driven decision making enlightens this study by reminding educators that they must determine assessment strategies and conduct item analysis to evaluate student strengths and weakness and decide on next steps with differentiated lessons. The IXL online program assists teachers in identifying struggling and accomplished students and allows for efficient re-grouping of students for remediation or enrichment. Further, how the technology is used relative to student mastery is critical especially as it relates to data driven decision making. Teachers simply cannot make assignments and input grades; the use of IXL in a vacuum does not produce good teaching and learning. "Some of the most-promising technology solutions do not move all instructional responsibility from teachers to technology but use the two in tandem, consistent with both learning science and evidence to date" (Pane, 2018, p. 8). Therefore, Data-driven decision making facilitates educators' responsibility to meet students where they are as learners, whether struggling or accomplished, and bring them towards mastery. IXL Math allows the efficient re-grouping of students based on their competency level and for teachers to offer remediation or enrichment. This is the real power of the IXL program – knowing who is struggling and who is succeeding, based on the data, and to offer differentiation of assignments. For example, teachers are able to review utilization levels of the IXL math program by students, specifically evaluating the number of questions answered, amount of time spent, and quantity of standards mastered. If a student answers hundreds of questions, or spends hours working on a topic, and yet, only achieves a mediocre score, then this student, while persevering, may be considered, "struggling." Clearly, the questions on IXL Math are very difficult for these students and the necessity for teacher intervention and differentiation is evident with the possible regrouping and re-teaching of students. Contrariwise, if a student answers several questions, spends a few minutes on the system, and achieves 100% score, then this student may be considered "accomplished." Clearly, the questions on IXL Math are not challenging for this students and their full potential will not be realized unless some differentiation occurs. Realizing how to effectively employ the online program greatly enhances student understanding and potential for mastery of content for all students. This is particularly critical to ensure the diverse needs and abilities of all students, especially those most at risk, are being addressed and met. This is where learning theories and models work together in complementary fashion.

In terms of this research's data analysis, the use of the two-way variance tests as well as the Pearson's coefficient to answer the research questions will help to assess the success of IXL Math treatment on student achievement on the New York State math exam. If there is a statistically significantly positive impact on student achievement for all students, by gender, ethnicity or disability, using IXL Math, then the use of the program may be justified. If not, then educators may need to adjust their instruction with better technological use or employing traditional methods, or both, to ensure that all students succeed. Further, if there a correlation between IXL Math usage, questions completed, and standards mastered and assessment performance, then educators should encourage greater usage of IXL Math by making more assignments within the online program or using effective student motivational methods provided by the system and other means.

Conceptual framework. The reliance and use of IXL Math exclusively may not be indicative of good teaching and learning. Teachers must not only know and understand what and how to teach, and to use technology effectively, but also, they must understand the learning theories, philosophies and best practices of teaching to effectively educate all students, especially the underserved sub-groups, to realize their academic potential. These three major elements of the conceptual framework: Zone of Proximal Development (ZPD), Differentiated Instruction (DI), and Data-Driven Decision-Making (DDDM), work together help to make content accessible and understandable for the student, and for them to achieve mastery. The components of the conceptual framework, working together in partnership, form the basis of excellent teaching and learning, especially when educational technology like IXL Math is employed. The interconnected nature of the elements can create a synergistic positive effect on the achievement outcomes with the teacher addressing the needs of all students regardless of their ethnicity, gender or ability.

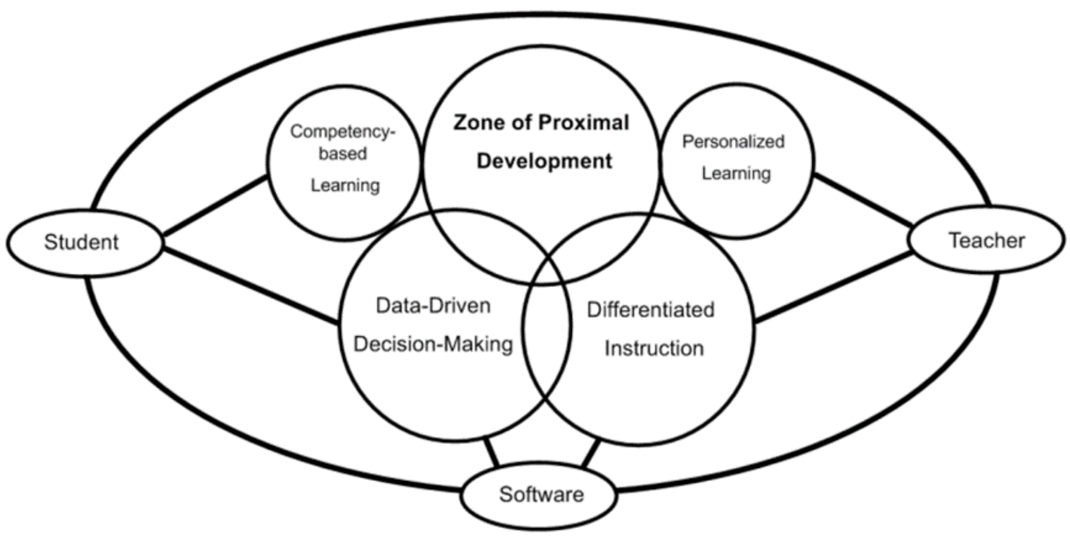


Figure 1.

Conceptual Framework of the Present Study

Rationale and Need for the Present Study

National performance levels. The National Assessment of Educational Progress (NAEP) measures what students in grades 4, 8, and 12 should be able to know and do in the content areas of reading, mathematics and science. It reports student academic performance nationally using a scale nomenclature of: Basic, Proficient and Advanced. The report in 2017 indicates that students' mathematics scores in grades 4 and 8, although improved, are “not measurably different than the score in 2015” (National Center for Educational Statistics, 2018.) Unfortunately, there has been not enough growth in mathematics knowledge and skill in these grades in over two years. A further review of the data indicates a disturbing trend. The percent of 4th grade students achieving a Below Basic performance level increased from 18% in 2015 to 20% in 2017 (National Center for Educational Statistics, 2018). More alarming is that the trend continued and became demonstrably worse by the time students were in 8th grade. For 8th grade students, the performance level of Below Basic, in the year 2015 was 29% and in 2017 that level increased to 30% (National Center for Educational Statistics, 2018). A comparison between the percentages of 4th grade students achieving Below Basic relative to their performance in 8th grade, strongly suggests that the gap is widening as students' progress in the mathematics education. (See Table 1).

Table 1.

US Dept. of Ed. Comparison of Below Basic Performance Levels

Year	4th Grade	8th Grade	Variance
2015	18%	29%	11 basis point increase in Below Basic Performance
2017	20%	30%	10 basis point increase in Below Basic Performance

New York State performance levels. For New York State, assessment results are equally disappointing. Although there was an improvement in the percentage of students who achieved proficiency in mathematics from 2017 to 2018, most students are still performing below expectations. The percent of students in grades 3 – 8 who achieved a performance level of 3 or 4 which is considered proficient, in 2017 was 40.2%, and in 2018, 44.5% (NYSED, 2018). This means that for two years in a row, nearly 60% of all students taking the math assessment performed below proficient. To put this is greater perspective, tabulation of the proficient and below proficient levels results in an alarming number of students who are unable to meet standard for their grade levels. On a state-wide basis 66% are below proficient scoring at levels 1 or 2 on the New York State mathematics assessment. In the county where the present research will be located, a slightly lower rate is reported at 53%, and the urban school district experienced a lower percent of students below proficiency levels at 44%. While no cause or effect statement is being made, the data demonstrates the serious need to increase the proficiency levels in the state, county, district and especially in the urban school where the research is being conducted. (See Table 2.)

Table 2.

NYSED Comparison of Scale Scores by Proficiency Level for the Site of the Present Study.

2018	Proficient (level 3 & 4)	Below Proficient (Levels 1 & 2)
New York State	45%	55%
Urban County	47%	53%
Urban School District	56%	44%
Urban School	28%	72%

National performance levels – ethnicity. An analysis of the scale scores by ethnicity (Black, White, Hispanic and Asian) confirms a concerning trend. Although the scale scores improved from 4th grade to 8th grade for each ethnicity, the data demonstrate that Black and Hispanic students perform lower as compared to the average, and far lower than White and Asian students. Repeatedly, National Center for Educational Statistics, 2018 makes the statement that the scores are "not measurably different" than those of previous years which means that again, there has been little to no success in closing the achievement gap. The scores of both Whites and Asians are higher than Blacks and Hispanics in both 4th and 8th grades (National Center for Educational Statistics, 2018). (See Table 3.)

Table 3.

US Dept. of Education. Comparison of Scale Scores by Ethnicity

2017 Grade	Black	White	Hispanic	Asian	Average
4th	223	248	229	260	240
8th	260	293	269	312	283

New York State performance levels – ethnicity. In New York State, the situation is nearly the same. In 2018, Blacks students' proficiency rate was 29.3%, Whites' was 54.2%, Hispanic was 31.8% and Asian was 71.2% (NYSED, 2018). This was a very small increase from the year before. In 2017, Blacks students' proficiency rate was 24.4%, Whites' was 50.4%, Hispanic was 23.4% and Asian was 67.2% (NYSED, 2018). While the data indicates a slight improvement in the proficiency rates from year to year, a huge chasm exists. In 2018, Black students scored nearly 25 basis points lower than White students, and Hispanic students scored 22.4 basis points lower than White students. The data indicates that nearly 71% of Black students and 68.2% of Hispanic students are scoring below the proficiency level. (See Table 4.)

Table 4.

NYSED Percent of Student Proficient in Grades 3-8 by Ethnicity for the Site of the Present Study.

2018	Black	White	Hispanic	Asian
New York State	29.3	54.2	31.8	71.2
Urban County	24.4	50.4	27	67.2
Urban School District	23	34	64	77
Urban School	16	23	37	52

National performance levels – gender. National Center for Educational Statistics, 2018 makes the statement that the scores for males and females are "not measurably different" between genders for 4^{th} and 8^{th} grades. An analysis of the scale scores by gender (Male and Female) illustrates the grave need of closing the achievement gap. Although the scale scores improved from 4^{th} grade to 8^{th} grade for each gender, the data demonstrates that the scores are have not changed for males and female students than those of previous years which means there has been little to no success in closing the achievement gap. (National Center for Educational Statistics, 2018). (See Table 5.)

Table 5.

US Dept. of Education. Comparison of Scale Scores by Gender

2017 Grade	Male	Female
4th	241	239
8th	283	282

New York State performance levels – gender. For New York State, the majority of grade 3 – 8 students whether male or female are performing below proficient on the state math assessment, with females scoring 1 basis point higher. Given the percentages report as scoring as proficient, the simple arithmetic reveals a disturbing fact – 56% of males and 55% of females are below proficient (NYSED, 2018). Additionally, since the school under examination is in an urban county, it is worth comparing the county scores with the rest of New York State. In the urban county, males scored a 47% proficiency rate slightly below females at a 48% proficiency rate. Again, while the proficiency rate is reported, one can determine the lack of proficiency by males and females with a simple computation. This data once again demonstrates that while the urban county performed better than the overall state, the percent of students scoring at below proficient is disheartening. 53% of males and 52% of females have scored below proficient. (See Table 6.)

Table 6.

NYSED Comparison of Percent Proficient by Gender for the Site of the Present Study.

2018	Male	Female
New York State	44%	45%
Urban County	47%	48%
Urban School District	55%	56%
Urban School	28%	27%

If this study finds a significant difference in achievement using IXL Math between male and female students, then attention should be paid to using different strategies for each gender to ensure mathematical achievement is attained.

National performance levels - students with disabilities. While the National Assessment of Educational Progress (NAEP) provides data on students with learning disabilities regarding the percent of student receiving services under the Individuals with Disabilities Act (IDEA), the percent by ethnicity, percent of students with amount of time in general education classes, and percent receiving a traditional high school diploma versus an alternative certificate, (National Center for Educational Statistics, 2018) after an exhaustive search, the report does not provide data relative to proficiency rates on the math assessment for students with disabilities in grades 4 and 8.

New York State performance levels - students with disabilities. Students with disabilities are especially vulnerable and exhibit a deficiency rate that is especially harmful to their future well-being. In New York state, students with disabilities achieved a proficiency rate of only 15% as compared to the general population of students at 51% (NYSED, 2018). Although the proficiency rate was higher in the county (19%) and the district (20%) than the state, these too are abysmal results. This is punctuated by the fact that in the school where the research is being conducted the proficiency level is more than sixty percent lower than the combined average of state, county and district results for proficiency. (See Table 7.)

Table 7.

NYSED Comparison of Percent Proficient by Students with and without Disabilities for the Site of the Present Study.

	General Education	Special Education
New York State	51%	15%
Urban County	55%	19%
Urban School District	63%	20%
Urban School	31%	7%

Significance of the Present Study

This study is significant because national, state and local measures indicate no measurable improvement in math achievement with a disturbing percentage of students scoring below proficient levels. Further, past studies examined teacher perception or student motivation regarding educational technology and achievement. To date, this is the only study independently analyzing the effectiveness of a widely-used online learning application, IXL Math, in a Title 1 urban Middle School consisting of 6th, 7th and 8th grade students and measuring the impact of the online program on students most at-risk, and whose attributes comprise the lowest third percentile of achievers.

Given a need to improve learning outcomes, it seems every teacher is looking for the “holy grail” of education to increase student achievement. One of the most sought after means of improving mathematical instruction in recent years is with educational technology. In fact, one of the statements published by the National Council of Teachers of Mathematics in its Principles and Standards for School Mathematics (NCTM) is "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student's learning" (NCTM, 2004, p.3)

In connection with this statement, the National Council of Teachers of Mathematics (NCTM) offers six guiding principles for educators to align their decision making as it relates to mathematical education. They are: Equity – where all students are subject to high expectations and support is provided to meet those challenging prospects; Curriculum – is a logical set of learning tasks and not a set of topics cobbled together; Teaching – educators must know what and how to teach content and to scaffold it so all student learn; Learning – students must not only perform mathematical procedures but also must make sufficient connection to and understand math concepts; Assessment – teachers must use data to inform their instruction and make curricula changes as necessary; Technology – an essential component as it impacts student learning of learning mathematics (NCTM, 2004.)

This study is significant because it addresses each of the six NCTM principles outlined above. First, since the goal of the research is to determine whether IXL-Math is significantly and positively impacting the student achievement of all students, notably those most at risk, it meets the equity provision of establishing challenging prospects for all students, especially the underserved. While every student has a computer or phone, and is provided with a school subscription, does every student have access to the content in order to succeed academically in math? Second, this study addresses curriculum and the need for educators to assign a cogent set of tasks within IXL-Math – each building on the other for students to build current skills and to prepare for the next set of skills. Are educators considering the pre-requisite set of skills before assigning new set of topics? Third, this study focuses on teaching, learning and assessment - knowing what to teach and how to teach it, providing differentiation and support, and using data to make decisions and necessary adjustments to curricula, and address student need by focusing on instructional gaps or enrichment opportunities. Are teachers using the system to enhance learning by using its capabilities of diagnostics and motivational devices? Lastly, this study speaks to the use of educational technology, IXL Math, and how it impacts student achievement. Is it worth the investment?

This study's findings will be useful to educational policy makers, school administrators, and classroom educators for it will offer insight into how educational technology in general and IXL Math online software in particular can be used more effectively to raise student achievement. First, it is critical in selecting a software package that the program chosen meets the educational objective. If the objective is skill building through the completion of a great number of practice questions, then IXL is an excellent resource. If not, then perhaps another software package would be more suitable. Second, if it is found that IXL Math does not have a significant positive effect, then educators may need to incorporate greater differentiation of lessons and assignments into their planning. They may need to offer a hybrid approach of instruction offering both technological and traditional methods, seeking the best practice to reach the educational goal. Third, if the utilization rate is not correlated with scale scores, then it is because some students do not "power-through" the challenge zone for fear of achieving a low SmartScore. Classroom teachers must be reminded of using the motivational devices within the system, as well as utilizing other means to encourage students to achieve mastery. Fourth, while IXL's strength is providing unlimited skill practice, it cannot address student mathematical misconceptions, nor does it connect multiple concepts together in one question or offer multi-step type problems. These type of questions regularly appear on the New York State Exam and it is necessary for all students to become proficient in answering them. Fourth, some students are able to achieve mastery in less than five minutes completing very few questions. Perhaps for these more accomplished students, IXL Math is not challenging enough, and enhancements can be made to the system to make questions more interesting and thought provoking. These two areas are where IXL software developers may consider improving upon.

St. John's University Mission

Since its founding as a Vincentian institution of higher education 150 years ago, St. John's University's mission has been dedicated to serving the educational needs of all people, especially the poor and disadvantaged. The university seeks to create real workable solutions to poverty and social injustice, while fostering respect, recognizing dignity, and promoting the care and compassion for all persons. On the wall of one of the campus' administrative buildings is inscribed the words: "Ministrare non ministrari" which translated from Latin into English means: "To serve not to be served."

It is in this spirit of generous service to others that this study aims to address the real educational needs of all students, especially those that are underserved by determining whether or not IXL Math has a significant positive impact in raising their achievement levels on the New York State Math Exam. By analyzing the benefits and potential gaps that exist in the use of IXL Math, this research will offer recommendations for future practice in supporting their students' achievement regardless of their background or ability, especially those that are disadvantaged, and most in need.

Research Questions

The following research questions are examined in this study:

1. Does IXL Math have a significantly positive impact on student achievement?
2. Are there significant differences in achievement by gender, ethnicity or disability using IXL Math?
3. Is there a correlation between IXL usage, questions completed, and standards mastered and assessment performance?

Definition of Terms

The following terms are defined to aid in reader understanding:

Achievement – A comparison of scales scores between the IXL Math Cohort and Non-IXL math Cohort

IXL-Math – a computer-based program offering limitless skill-based practice utilizing a tiered approach to provide increasingly difficult questions.

IXL-Math Cohort – Three grades of students using IXL Math for homework and classwork assignments.

Non-IXL-Math Cohort – Three grades of students using not IXL Math and instead receive traditional paper-based work for homework and classwork assignments.

Usage – the number of minutes a student utilizes the IXL program not including idle time. (IXL, 2018)

Mastery - a score of 100% on an individual skill. (IXL, 2018)

CHAPTER 2

Review of Literature

The purpose of this study is to evaluate the effectiveness of IXL Math online software in raising student achievement on the New York State Math exam, with special focus on effects by student gender, ethnicity and disability status. Chapter 2 will examine the literature relevant to this study of IXL Math on student achievement in an urban middle school. The Chapter begins by summarizing the findings of recent meta-analyses on the outcomes from technology integration in classrooms, including a comparison of technology-based and non-technology-based strategies. Following broad findings, specific studies that focus on the effects of using technology for mathematics learning in K-12 classroom settings are reviewed, with a focus on the subgroups addressed in the present research (gender, ethnicity, and disability status). The few independently conducted research studies on the IXL Math software are included here.

Since the present study examines outcomes from use of IXL for homework in mathematics, relevant studies on outcomes from technology-based homework support are reviewed. Further, the need for professional development of educators to fully maximize student learning using educational software products will be discussed from the perspective of teacher attitudes, efficacy, and learning needs.

Theoretical Framework of Technology-based Instruction

The IXL software examined in the present study is designed based on certain principles of learning that have been applied to instructional materials in other domains. IXL is ued for practice and skill building. It offers personalized "instruction" but does not deliver new content. It does adjust to student learning levels by providing more difficult questions and a motivational statements, like "Good Job" with each correctly answered question, and provides immediate feedback with an explanation as to the correct solution for eqach incorrect answer. There is audio avaibale for those students who need read-aloud to understand the question more fully. IXL is built on personalized learning, adaptive technology, competency-based learning, zone of proximal development, and motivation. It tracks progress by measuring the number of correct and incorrect answers for each topic and offers a "Recommendations" tab for studnts to indpendently practice. As such, the design of IXL adheres most closely to the theory of memory activation and storage proposed by Shiffrin and Atkinson (1969), and observational learning offered by Bandura (2004), and automaticity development as described by Logan (1988).

Model of memory. Shiffrin and Atkinson (1969), proposed a theoretical framework of human memory dividing it into three distinct areas within the brain: sensory register, through which information is received through the senses, short-term store, and long-term store. Key to their hypothesis is the subject governs all aspects of memory deciding on information processing, search and retrieval strategies. Their theory accentuated that information processing is regulated by the control processes of coding, rehearsal, retrieval, and search strategies. According to the researchers, the sensory register temporarily stores information received from the environment and transfers it to the short-term store. The short-term store, considered working memory, processes information by activating the rehearsal device, initiating the response generator which will continue the search process or emit a response, or transferring the information to long-term store. Transfers of information to and from short-term store and long-term store are done so not by removing data, but rather by copying data and moving it to a new location. The information is permanent in long-term store.

The authors explain that the organization of memory impacts the storage, search and retrieval process. This begins with the person encoding the information, that is, the information is changed into visual, acoustic or semantic representations. Then, the person decides where and how to store information in either one or more storage locations. This is called self-addressing. The retrieval process involves searching memory in one location and moving to the next until the information is found. The more specific that information is coded and stored, the less searching is required because it is more easily retrieved. The less specific that information is coded and stored, the more searching is required because it is more difficult to be retrieved. Forgetting information is indicative of an ineffective search and retrieval system caused by decay or interference. This is the reason why rehearsal is necessary to maintain the information in memory.

Shiffrin and Atkinson's theory of memory includes a description of a response generator which continues or terminates the search and retrieval process as information is retrieved and an output is emitted. It is a process that repeats and never ends – placing information into long-term store from short-term store and retrieving information from long-term store and into short-term store. This is aided by a control process of rehearsal which maintains information within short-term store for as long as necessary, and by cycling through the process, the information builds permanence in long-term store. The researchers report that experimental evidence suggests that rote rehearsal leads to improved performance.

Lastly, long-term memory is divided into two parts: explicit and implicit memory. Explicit memory is the type where a person purposely works to remember information; it is conscious awareness. Implicit memory is formed from behavior and considered automatic by using experience to remember; it is unconscious awareness. Explicit memory is divided further into episodic and semantic memory. Episodic memory is information about personally experienced events. Semantic memory is used to remember language-based knowledge and facts. Implicit memory also has two parts: emotional conditioning and procedural memory. Procedural memory is information stored about how to perform step-by-step tasks and skilled activities. (Tulving, 1972) Emotional conditioning is recalling the feelings pertaining to a person, place or event, evoking an emotional response when recalled.

Observational learning. Fryling, Johnston and Hayes (2011) describe Albert Bandura's theoretical framework of observational learning. The theory consists of attention – recording sensory information and concentrating on the activity to be learned; retention – holding information in one's memory and recalling it when required; reproduction – learned information stored in memory whereby one can replicate a behavior, skill or knowledge when necessary; and motivation – the determination to perform an action by witnessing positive or negative consequences. Both attention and retention are acquired skills, whereas reproduction and motivation are performance-based attributes. The theory is important for students because modeling is an important method of learning, especially if they see incentives for certain behaviors, or penalties for certain others. The researchers' review of the theory indicates that behavior can change through observation, and that consequences, both positive and negative, can influence behavior.

Rewards create more change and punishment creates less change. Further, there is a difference between learning a task and performing the task. Learning is revealed by verbal description of what was observed, while performance is demonstrated by engaging in the learned behavior. When subjects can perform an activity without modeling, it is said to be generalized; that is, the behavior is imitated without observation. The researchers state that subjects behaving according to a model strengthens the desired behavior itself. However, one cannot ignore the stimulus-response function characteristics of inter-behavioral psychology as it relates to observational learning: that learning is both interactional and relational. The authors posit that imitation, reinforcement, rules-based behavior and verbal processes are also components of observational learning. A further examination of cognitive factors reveals that participants who described an observed activity (coded) and then practiced that activity immediately afterward (rehearsal) had better outcomes.

Automaticity. Logan (1988) proposed an instance theory of automaticity. The theory has three main assumptions. First, encoding into memory is an inescapable byproduct as a result of attention. Whether information is remembered well or not, it will be encoded. Second, retrieval from memory is an inevitable result of attention. Retrieval will happen even if it is unsuccessful. Third, every act of attention is coded, stored and retrieved individually. The assumptions indicate a learning process, as the theory is connected to episodic memory, semantic memory, categorization, judgement and problem-solving. In his experiments, the theorist reported that when subjects performed repetitive mathematical tasks, the question types and the respective problem-solving methods were coded into memory. As additional questions and problem-solving strategies were presented, they were included into working memory. Improved performance, based on automatic retrieval from memory, was reported; the processing of mathematical tasks increased in speed, and the variability in responses was reduced through practice. Subjects adjusted from completing complex computational procedures to simply using memory-based strategies; building “automatization” and skill acquisition by repeatedly solving mathematical questions.

The unique features of the IXL online math software are: (a) provides unlimited access to question types for each standard; (b) adjusts to student’s learning level by increasing or decreasing the question’s degree of difficulty; (c) provides a preview of problems and solutions as a model for students to follow before they begin work; (d) offers immediate feedback with motivational statements, like "Good Job" with each correctly answered question, and provides explanations as to the correct solution for each incorrect answer; (e) allows teacher to monitor progress with various reports.

Relative to Shiffrin and Atkinson’s theory of human memory, rehearsal in short-term store is necessary in order for information not to decay and to become permanent in long-term store. The online drill and practice feature of IXL Math, as students work towards mastery, offers unlimited number of questions for students to complete. This attribute offers an abundance of opportunities, unlike paper homework, for students to gain valuable repetitive practice as they strengthen their short-term and long-term memories. The large quantity of problem-solving activities builds implicit memory for the correct procedure of each question type furthering students’ knowledge and skill acquisition. If a student answers correctly, the system displays a positive statement, and the act of moving onto another questions knowing one performed well reinforces the learning. When a student answers a question incorrectly, the IXL system provides an example, and this activates explicit memory, as the student purposely reviews the steps, makes corrections, and moves on to the next question. The dynamic of activating implicit and explicit memory through the unlimited practice of the IXL software creates permanence in long-term memory, and develops an efficient storage and retrieval system, making the student more skillful.

Regarding observational learning, after a student logs into the IXL Math software, and proceeds to the assigned topic to complete, their attention is activated by reading the problem, and if they wish, listening to it read aloud to them. Their memory can also be stimulated by reviewing the question and solution example provided before they begin work. Using this IXL feature, students can imitate the solution by what they have observed. Additionally, IXL offers alternative topics for students to complete if they are not ready to complete the assignment. This feature helps to bridge the skill gap and build confidence before attempting to do the work. If students answer correctly, their behavior will be reinforced as they will receive a positive statement, like “Good Work”, as well as additional awards like medals and badges that are displayed on the screen. The negative consequence for answering incorrectly is not moving up to more difficult questions, and not achieving mastery. However, the negative consequences of incorrect answers in the “Challenge Zone” increase dramatically. In this case, IXL will drop a student’s score by no more than 8 points. For those students who make it through successfully the experience is very rewarding.

With respect to Logan’s instance theory of automaticity, it is evident that the more students practice using IXL, the greater their procedural skill becomes. The ability to replicate solutions to various questions strengthens every act of attention and reinforces coding, storage and retrieval of information. Working memory becomes automatic. The IXL system will automatically adjust to a students' level if the questions are too difficult and provide easier questions allowing students to reunite with information in their memory and compete problems with which they can work. As students answer several questions in a row correctly, they may have reached their level of automaticity, and IXL will provide more challenging questions, and this new information needs to be practiced and reinforced. Additionally, IXL Math provides "Recommendations" of various topics that students can self-select to complete based on a continuous diagnostic and the need to address skill deficiencies, or the added encouragement to try more challenging questions.

The three theories regarding the inner workings of human memory presented in this study support the use of IXL as an online platform to strengthen student skill and knowledge with continuous and limitless practice. IXL's ability to deliver numerous questions for students to complete until one has achieved mastery builds an efficient coding, storage and retrieval process in short and long-term memory, makes procedural information capable of being recalled when necessary, provides incentives to continue practicing thus reinforcing the learned information, and creates an automatic process in the mind of the IXL user. The more students practice using IXL, the easier it is for them to remember how to solve problems and apply their skills linking the question type with the correct solution strategy.

Technology-based Instruction in the Classroom

Research demonstrates that technology integration into the classroom can enhance student learning. Zengin (2016) examined the effect of a flipped classroom using Khan

Academy and a free online software, GeoGebra and Maxima, on student mathematical achievement. There were 28 students (10 male and 18 female) involved in the study, and the research treatment lasted for 8 weeks. A pre- and post-test analysis was performed on the scores of the Double Integral Achievement Test (DIAT). The data analysis indicates that the students' DIAT scores achieved after the flipped classroom was enacted (*Mdn* = 23) were significantly higher than before the implementation (*Mdn* = 3) scores of the test, $z = -4.21$, $p < .05$, $r = -.62$. Further, the mean students' pre-test mean score increased from 1.69 to the post-test mean score of 21.82 – substantially higher. Based on these results, the author concluded, "the flipped classroom approach designed using the Khan Academy materials and the mathematics software was an effective approach to increase students' achievement." (p. 93) The data shows that students' understanding of the mathematical concepts were enhanced through the flipped classroom approach using Khan Academy and the mathematics software combined.

Gatti (2013) conducted a study of SuccessMaker, to determine if the online learning system used for Response to Intervention students would show significant improved achievement over conventional supplemental intervention instruction. Students in 3rd and 5th grade from 18 schools in 6 states (AZ, CA, KS, MI, OR, and TX) were randomly assigned to either SuccessMaker intervention or to a non-computer-based intervention program. Students using SuccessMaker received 4 sessions of interventional program time each approximately 20-30 minutes in duration in an educational laboratory. Students in the non-SuccessMaker group received regular supplemental mathematics instruction as Response-to-Intervention. There were 292 students in the 3rd grade with 154 receiving SuccessMaker intervention, and 138 receiving non-Successmaker intervention. In the 5th grade, there were a total of 490 students of which 239 received SuccessMaker intervention, and 251 experienced non-Successmaker intervention. The instrument to measure achievement was Group Mathematics Assessment and Diagnostic Evaluation (GMADE), a standardized, nationally norm-referenced achievement test. A beginning-of-year and end -of-year rests were administered for comparative purposes in order to measure growth. The outcome was statistically significantly positive (ES = +0.33, $p < .05$). The significant gain in math achievement demonstrates that a diverse population of at-risk students can succeed using an online system.

Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011) conducted a syntheses of meta-analyses of research on technology-based instruction in the classroom over the past 40 years. 25 unique full text articles met the inclusion criteria of a) technology utilization in the classroom, and b) student achievement. The purpose of the investigation was to compare the effect of technology in the classroom with traditional classroom instruction. The meta-analysis found a significantly significant, small to moderate positive average effect size with computer-assisted instruction. Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011) concluded, "the average student in a classroom where technology is used will perform 12 percentile points higher than the average student in the traditional setting that does not use technology to enhance the learning process" (p. 17). However, the authors note that the effectiveness of educational technology is dependent upon the instructional design, pedagogical approaches and teacher practice (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011).

Additional research found that the type of feedback received by a learner in a computer-based setting can positively and significantly impact outcomes. Using a mixed model for data analysis, with an independent variable of feedback type via technology, a meta-analysis of 40 research articles, Van der Kleij, Feskens and Eggen (2015) examined the effect size of feedback on learning outcomes in a computer-based setting. They concluded that elaborative feedback - the provision of subtle hints and specific explanations, was more effective than obtaining the degree of correctness of the solution, or simply being told an answer is correct. In this study, the effect size of elaborative feedback was 0.49, moderately high as compared with simply providing information about the correct response, and for mathematics was 0.93, exceptionally high as compared with other subject areas investigated, after both calculations were adjusted for the small sample size. In terms of elaborative feedback, the authors state, "…subtle guidance might be generally more effective than highly specific guidance," (p. 502). The study further indicated that immediate feedback was more effective than delayed feedback. This immediate and individualized feedback to specific question types is another advantage of using educational software.

Technology-based Instruction in Mathematics

Research (Higgins, Huscroft-D'Angelo & Crawford, 2017) shows that technology use in the classroom has improved students' learning experience of mathematics by positively impacting students' mathematical achievement and contributing to their attitudes and increasing their motivation. A meta-analysis of 24 research articles (4,522 subjects) examined the effect sizes of technological interventions on mathematics achievement and motivation and attitude. Eligibility for inclusion was a) technology was utilized as treatment for instruction and measured the effectiveness on math achievement and motivation or attitude, b) studies conducted in K-8 grades, and c) spanned nearly 30 years of research (1985-2013.) The authors stated that they found a statistically significant mean effect size of 0.68 on mathematics achievement, a mean effect size of 0.30 on motivation, and 0.59 effect size on attitude when technology was used as an instructional intervention as compared to when it was not. Interpreting these results, the authors concluded that technology had a moderate to strong impact on student mathematical achievement, and a moderate impact on motivation and attitude as compared to traditional instructional methods. Higgins, Huscroft-D'Angelo & Crawford (2017) provided the practical implications of this meta-analysis with this statement: "Educators and administrators must consider the type of technology to implement in the classroom, the duration of technology use in the classroom when used as an intervention, and the mathematical content being taught." (pp. 311-312).

However, some computer-assisted programs have not produced a significant effect on students' mathematical achievement. According to a best-evidence synthesis of 78 studies evaluating 61 programs in grades K-5, Pellegrini, Lake, Inns and Slavin (2018), reported that the combined weighted mean effect size of such programs was +0.07 (k =14, p = .05). The majority of programs included in the study had no statistically significant effect on student mathematical achievement. The authors reported on the following computer-assisted programs: Accelerated Math, that assess student levels of performance and assigns personalized topics to meet student need demonstrated a mean effect size of +0.03 with no significant effect found in any study. DreamBox Learning which provides feedback to teachers on student use and progress found a non-significant mean effect size of +0.11, *ns* randomizes trial of kindergarten and 1st grade students. Educational Program for Gifted Youth (EGPY) uses multimedia lessons and tutorial support for struggling students reported no significant effects. (*ES* = -0.01, *ns*) in a randomized trial of 2^{nd} to 5^{th} grade students. Odyssey Math, which provides learning activities, assessments and math tools found no significant effects (*ES* = +0.02, *ns*) with a randomized trial of 2^{nd} through 5^{th} grade students. ST Math uses spatial and temporal depictions to teach mathematics with students participating in solving math questions one hour to an hour and a half every week. The study found no significant effects (*ES* = +0.08, *ns*) in a randomized trial of 3^{rd} to 5^{th} grade students. Pellegrini, Lake, Inns and Slavin (2018) stated, "Collectively, the studies found that it matters a great deal which programs and which types of programs elementary schools use to teach mathematics." (p. 38) Since, the educational technology produced small positive effects that were statistically insignificant, the authors reported that the study did not provide strong backing for any specific technology application. They conclude that the results point towards educational technologies that accentuate personalization, engagement, and motivation have the most impact on mathematics instruction.

Yet, there are several online programs that have produced positive results. A study (Bennet, 2010) comparing the impact MOVE IT™ Math software and traditional textbook instruction to learning mathematics collected data from 100 5th grade students and compared the results on the Georgia Criterion Reference Competency Test. The student population was 100% African-American. The researcher conducted a quasi-experimental design using a t-test and chi-square to compare two treatments: one group of students using MOVE IT™ software and the other receiving traditional instruction. The results indicated that there was a statistically significant difference between the two groups, t (98) = 3.05, p = .003. The MOVE IT Math™ group scored significantly higher

(*M* = 838.96, *SD* = 31.49) than students in the traditional textbook group (*M* = 821.78, *SD* = 24.36). The researcher concluded that there was a significant difference between the two groups – the MOVE IT™ math software program increased student performance.

Brasiel, Jeong, Ames, Lawanto, Yan and Martin (2016) performed an extensive evaluative study of online educational products used in mathematics instruction. Their purpose was to determine the impact of educational technology on student proficiency levels on Utah's state summative assessment. The products were: ALEKS®, Catchup Math®, i-Ready®, MathXL®, ST Math®, SuccessMaker®, and Think Through Math®. The authors estimated the impact of technology through a quasi-experimental approach by using a propensity-score matching comparing students' state assessment 2014-15 scores using the software to the 2013-14 state assessment scores of students experiencing business as usual instruction. The online products were used by 152,276 students throughout the state. Since the year-over-year assessment data was not available for all students who used the products, the final sample consisted of 44,497 K-12 students. A logistical regression was used for the data analysis, and the authors reported the odds ratio, standard error, *p*-value, effect size and 95% confidence interval of the odds ratio for each product. All products, except i-Ready®, resulted in an odds ratio greater than 1.0, which means that the educational technology used in mathematics instruction had a positive influence in student achievement on the state mathematics assessment. All products exceeded the 0.16 effect size, meaning that technology-based instruction had a positive effect on student proficiency levels as measured by the state mathematics assessment. Only two products, ALEKS® (*ES* = .18, *p* = 0.032) and i-Ready ® (*ES* = .62,

p = .002), had a statistically significant impact on achievement where the benchmark utilization levels suggested by the software publishers were adhered to with fidelity.

Additionally, the authors surveyed 2,933 teachers regarding their utilization of the online products. 58% of teachers reported using the technology as a supplement to regular instruction, 28% used online software as an intervention, and 53% assigned product use to students as homework. The authors note that all the online products allow students to work at their own pace, access above and below grade level material (except ST Math®) and receive real-time feedback. Teachers can meet the needs of all students by gathering data, differentiating lessons, and monitoring progress. The potential for using educational software in mathematical instruction to increase student achievement is evident.

Technology in mathematics instruction by gender. Motivation and engagement may be influenced by gender. Hatfield (2019) employing a causal comparative, non-experimental study examined if differences existed between genders on motivation and engagement using a mathematics intervention online program called ST Math (ST is an abbreviation for spatial-temporal). ST Math® uses visual representations such games, virtual manipulatives and puzzles to help teach mathematical concepts. Much like IXL Math, the program provides immediate feedback and students can work at their own pace as they progress from one level to the next by obtaining a 100% score. A sample of 160 4th grade students were equally divided (80 in the treatment group using ST Math®, and 80 in the control group experiencing traditional instruction.) Gender type was also equally divided with 40 males and 40 females in both treatment and control groups. The instrument used was the Motivation and Engagement Scale (MES)—Junior

High (JS). A factorial ANOVA was used to analyze the interaction effect and the main effects of gender (male versus female) and participation in ST Math® intervention. The results indicated no significant interaction effect between ST Math® participation status and gender, and motivation, $F(1, 156) = 0.28$, $p = .596$, $ES = 0.002$, and no significant interaction effect between ST Math® participation status and gender, and student engagement, $F(1, 156) = 0.93$, $p = .337$, $ES = 0.006$.

However, the main effect for gender and motivation was significant, $F(1, 156) = 8.16$, $p = .005$, $ES = 0.050$, and the main effect for gender and engagement was significant, $F(1, 156) = 16.68$, $p = .000$, $ES = 0.097$. For student motivation, the mean of the females ($M = 50.85$, $SD = 7.09$) was significantly higher compared to the mean of the males ($M = 47.23$, $SD = 8.83$). For student engagement, the mean of the females ($M = 51.99$, $SD = 5.84$) was significantly higher compared to the mean of the males ($M = 47.38$, $SD = 8.20$). Overall, females scored higher than males on motivation and engagement whether or not they participated in the ST Math® intervention.

One implication offered by this research is enhanced motivation and engagement may translate into higher academic achievement. The author also posited. "…males are more motivated by tangible, measurable results, and females are more motivated by intangible rewards such as acknowledgment for task completion" (p. 79). Educators would be well served to consider the differences in genders in terms of how to motivate and engage students when utilizing educational technology.

Spradlin and Ackerman (2010) conducted a quasi-experimental study using a pre- and post-test design to compare student achievement in developmental mathematics using computer assisted instruction (CAI) versus traditional instruction. Student participants in the study were from four sections of Intermediate Algebra at a large, private, eastern university. The treatment group was comprised of 51 students (21 male and 30 female) and the control group consisted of 48 students (23 male and 25 female) for a total of 99 students. The difference between the treatment and control groups was students in the treatment group utilized a computer learning system including a tutorial to complete assignments. ANCOVA was conducted to determine if there were significant differences in mathematical performance between the two methods of instruction.

The results indicated there was no statistically significant difference for method of instruction, $F(1, 94) = 2.35$, $p = .13$. Yet, the results indicate a significant difference for gender, $F(1, 94) = 10.45$, $p = .002$. There was a statistically significant difference in post-test mean scores of male and female students. Further, the mean test scores indicate that females ($M = 79.84$; $SE = 1.768$) scored higher on the post-test than males ($M = 71.26$; $SE = 1.97$). The results also indicate that there was no significant interaction between method and gender, $F(1,94) = .07$, $p = .79$. However, analyzing the data presented in the study one can conclude, while female students outperformed male students in both computer-assisted and traditional instruction methods, male students' mathematical achievement increased the most with computer-assisted instruction.

Vale and Leder (2004) conducted an ethnographic study utilizing classroom observations, interviews and an open-ended questionnaire to measure the perception of male and female students within computer-based mathematics lessons. Specifically, data was collected relative to student attitudes and use of computers in a mathematics classroom. A sample of 49 junior high school students participated in the study comprised of 17 females and 32 males from 8th and 9th grades. Laptops were in the classroom to access the software, Geometer's Sketchpad for the lessons. Geometer's Sketchpad allows students to learn mathematics with visual representations and dynamic modeling. The software is used to illustrate mathematical concepts and to provide engaging learning activities which should lead towards increased understanding and achievement. Additional technology such as Excel and PowerPoint were introduced into the lessons for students to make presentations regarding their various solutions. The data was triangulated to increase the validity of the results.

Four major themes emerged from the qualitative data: a) pleasure - enjoyment using computers, b) success – technology made learning math easier, c) relevance – learning computer skills while learning math, and d) power of technology – computers were an efficient tool. The female point of view about using technology to learn math was more about success and pleasure. It was reported that girls considered computers valuable because it made learning mathematics easier; computers enhanced their learning experiences because the device served as an aid. They were comfortable and enjoyed using computers. On the other hand, the male point of view was more about pleasure and relevance. It was reported that boys experienced pleasure using the computer because it helped them to learn mathematics, and computers provided relevance to the math lessons. However, it was noted that the boys were more often off-task when using a computer. Although there were gender differences in perceptions relative to three of the themes, both male and female students positively perceived the power of technology as computers offering efficiency in learning mathematics.

Quantitative data regarding the relationship between student gender and attitude about using technology in the mathematics classroom was captured in an Attitude to

Computer-based Mathematics Scale which the authors define as “the degree to which students perceive that the use of computers in mathematics provides relevance for mathematics, aids their learning of mathematics and contributes to their achievement in mathematics’ (p. 291). Male students were more positive about computer-based learning of mathematics than female students. This finding was statistically significant ($F(1,44) = 20.35$, $p = .00$, partial $\eta^2 = 0.36$) and indicates that gender is an influence on student attitudes with respect to computer-based instruction in mathematics. The authors conclude that given the gender differences in perspective and attitude of utilizing computers in the classroom, educators should consider different approaches for each gender to improve the attitudes and learning of mathematics of male and female students.

Brown (2018) studied the relationship between IXL online practice and mathematical achievement and gender, comparing the online system of completing homework (treatment group), with traditional paper and pen completion of homework (control group). The sample consisted of 172 students in the 7th and 8th grades in a middle school in East Tennessee. The students’ grade point averages were used to compare the 2015-16 (paper and pen group) grades to the 2016-17 (IXL group) grades. There was no change to the teacher assignment or instructional approaches from year-to-year. Teachers were allowed to assign as much or as little homework as they chose. Students in the IXL treatment group were directed to obtain a score of 90% on every homework assignment. A paired samples t-test was used to analyze the data. Results indicated that the mean for paper and pen homework condition was higher ($M = 88.91$, $SD = 8.72$) than the IXL condition ($M = 81.93$, $SD = 15.25$). The results were statistically significant, $t(170) = 5.15$, $p < .001$). With respect to gender, an independent t-test was conducted and found that there was no significant difference between male and female student scores when using IXL for homework completion. Although the female students' mean (M = 82.65, SD = 15.59) was a little higher than male students' mean (M = 81.20, SD = 14.95). The researcher concluded that although there was significant difference between IXL and paper and pen homework completion, there was no significant difference between male and female students using IXL for homework completion.

Feng, Roschelle, Mason and Bhanot (2016) conducted a study to investigate gender differences in homework completion and utilization rates on the ASSISTments educational software in 7th grade classrooms. Teachers select homework topics on the system for students to complete, and while completing assignments students receive feedback and tutoring as necessary. It is thought that students do more homework and learn more mathematics by using the ASSISTments program. The sample consisted of 1033 7th grade students (515 boys and 519 girls) that were randomly assigned to the computer-based treatment group or to the business as usual control group. A TerraNova Common Core Math exam was administered to both groups at the end of the academic year to measure increases in student mathematical achievement. The researchers reported a somewhat weak but positive relationship ($.2 < r < .4$) between the TerraNova scores and system utilization. This implies that greater utilization of the educational technology to spend more time and complete more homework questions will result in higher scale scores on mathematical achievement assessments. However, the authors raised the questioned as to which gender advanced more from the online homework intervention. Using a Hierarchical Linear Regression Model for analysis, the data revealed that the interaction effect between gender and achievement was significantly different (g = 7.476, $t(42)=2.232$, p =.031). The authors conclude that the technology intervention benefitted boys more than girls, and helped close the achievement gap between boys and girls on standardized testing. The authors provided several important considerations that influence the relationship between technology utilization and achievement: a) quality time on task, not just the number of minutes spent, b) effort and perseverance to complete homework, and c) frequency of homework completion are all more reliable predictors of student achievement.

Technology in mathematics instruction by ethnicity. Research (Huang, et al. (2013) has shown that intelligent tutoring systems can help close the mathematical achievement gap between white and black students. The study examined the effectiveness of a tutoring system called ALEKS, which stands for Assessment and Learning in Knowledge Spaces, in reducing the knowledge gap of 6^{th} grade students. The study was performed in five secondary schools in west Tennessee serving mostly economically disadvantaged and minority students. 102 students participating in the study were randomly assigned to one of two groups: the ALEKS tutoring system or the traditional form of instruction with a human teacher. The ALEKS condition group consisted of 28 males and 23 females, of which there were 11 white students and 40 black students. The teacher condition group was made up of 22 males and 29 females, of which 11 were white students and 40 black students. The instrument used to measure mathematical performance was the Tennessee Comprehensive Assessment Program (TCAP) and a comparison was made using ANOVA testing on student scores from 5^{th} to 6^{th} grades. The result of the analysis indicated that there was a statistically significant 3-

way interaction between ethnicity, gender, and condition $F(1,93) = 5.35$, $p = .02$. The authors report that in the 5th grade, there was an achievement gap between black male and white male students, but that was largely eliminated by the 6th grade. Huang, et al (2013) contend that this is due in large part to the ability of the ALEKS program to meet the individual needs of students. This study suggests that educational software can help close the achievement gap for minority students.

Ahn, Beck, Rice and Foster (2016) conducted a regression analysis of 9,204 4th through 8th grade students' time on task working with First in Math (FIM), a web-based software program designed to improve computational skills, and their scores on the 2012-13 DC Comprehensive Assessment System (DC-CAS) which students take at year end. Prior year grade level exam results were used as the pre-test to compare mathematical achievement. The regression model included investigating the association between student attributes (gender, special education status, race) and achievement. The findings were significant and indicated that female students' usage of FIM was 40 minutes less than male students' usage per year ($B = -0.662$, $SE = 0.144$, $p < .05$), special education students used the program 36 minutes less than non-special education students per year ($B = -0.615$, $SE = 0.207$, $p < .05$), and Asian ($B = 3.79$, $SE = 0.567$, $p < .05$) and Black students ($B = 3.23$, $SE = 0.280$, $p < .05$) and Hispanic students ($B = 2.91$, $SE = 0.362$, $p < .05$) utilized the FIM system nearly 3 hours or more per year than White students The authors note, "If we assume that FIM use is a positive activity (e.g. correlates to improved academic achievement, …it is heartening to observe that students of color are exhibiting more use than their White peers" (p. 6) Subsequently, the researchers report a significant correlation between utilization levels and improved mathematical achievement for female, special education and black students. While a correlation exists, the researchers stipulate that there is no causation between utilization and achievement, yet they proceed to predict that using the FIM software for 20 hours a year, or about 30 minutes per week, would result in an increase of about 0.14 *SD* in a students' ranking relative to one's peers. The study demonstrates that increased utilization of the online program by female, minority and at-risk students has the potential of increasing mathematic performance.

Park, Lawson and Williams (2012) conducted a study of the relationship between technology use, gender, parent education, self-confidence and academic aspiration as predictors of mathematical achievement with Hispanic students not born in the United States. Participants in the study were 367 8th grade students (183 girls and 184 boys). Of the sample, 57 students settled in the U.S. when they were 10 years or older, 128 students moved to the U.S. when they were between 5 and 10 years old, and 182 students immigrated to the U.S. when they were younger than 5 years old. The study hypothesized that there would be a significant difference between the means of the three groups of immigrated Hispanic students. The authors posited that technology usage, gender, and parent education would have a significant influence on students' math achievement. Mathematical achievement was determined by the proficiency scores of students on the 2007 Trends in International Mathematics and Science Study (TIMSS). Educational technology use consisted of word processing, web browsing, email, and graphic arts, and a survey was used to ascertain how often students used computers for schoolwork: every day, once per week, once or twice a month, a few times per year, or never. A multi-group analysis using AMOS revealed that gender and parent education were not significant predictors on math achievement. The analysis also demonstrated that the predictor variable of technology usage of Hispanic students who immigrated later (more than 10 years old) was positively associated with mathematical achievement, and derived they most benefit (*b* = 17.83, *SE* = 6.23, *b* = .32, *p* <.001). The implications of this study reveal that educational technology can have a positive influence on Hispanic students' mathematical achievement, and that students who have immigrated to the United States in the later years of age can benefit the most.

Technology in mathematics instruction for students with disabilities. Computer-assisted instruction (CAI) may help educators meet the academic needs of students with learning disabilities. Xin, et al. (2017) conducted a study, funded by a grant by the National Science Foundation, on the effects of an intelligent tutor program on the mathematical skills of students with learning disabilities. Comparing computer-assisted instruction (CIA) with teacher-delivered instruction (TDI), the study's goal was to determine which method was more effective in improving elementary student's multiplicative problem-solving skills. The sample participants were comprised of 17 elementary students in the Mid-west who were randomly assigned to one of the treatments by flipping a coin. There were 6 males and 3 females in the CAI treatment, and 4 males and 4 females in the TDI treatment. Pre- and post-test scores on the Stanford Achievement Test was used to measure the effects, along with several subsequent post-tests to measure improvement over time. That is, to determine if the improvement was maintained. The intervention consisted of 4 sessions per week, for about 25 minutes each, for approximately 9 weeks (36 sessions.) The CAI incorporated a specialized scaffolding system that included several levels of prompting. Utilizing a heuristic approach to problem-solving combined with modeling and visual representation, the CAI system, entitled Please Go Bring Me-Conceptual Model-Based Problem Solving (PGBM-COMP), is designed with instructional strategies shown to be effective for students with learning disabilities in mathematics. Using independent sample t-test, while the results indicated a no significant difference between CAI and TDI groups, $t = -1.77$, $p = .10$, there was a statistically significant effect of group and time ($F = 5.36$, $p < .013$) indicating that the CAI group was much greater. The authors indicated that the results support the idea of using computer-assisted instruction programs to increase the problem-solving skills of students with learning disabilities in mathematics. Additionally, the authors offer practical implications regarding their research: "It should be noted that when using this high-tech intelligent tutor, the main role of the teacher is a problem solver and facilitator of learning (p. 15). Educational technology has the potential to provide the support for learners with various abilities – especially those with special needs.

Stultz (2013) conducted an experiment to test the idea whether or not computer-assisted instruction was as effective as teacher directed activity for students with specific learning disabilities. A sample of 58 high school students (36 males and 22 females) in the 10th grade was randomly assigned to one of two groups – the computer-assisted instruction group or the teacher directed activity group. There were 18 boys and 11 girls assigned to each group. A pre-test, the Brigance Comprehensive Inventory of Basic Skills - Revised was administered as a baseline measurement of achievement, and the same test was given to both groups at the end of the experiment to measure the change in achievement. Both groups received 10 sessions of 90 minutes each for a total of 15 hours of instruction, and the curricula was the same as verified by an independent mathematics professor and two mathematics teachers from the same public school. The reviewers agreed at the 91.7% level as to the instructional contents' equivalence. The teacher directed activity group received direct instruction, guided practice and completed paper and pencil worksheets and quizzes. Students were required to meet a benchmark of 70% correct before progressing to the next topic. The computer assisted instruction group utilized the Basic Math Competency Skill Building Program for Fractions, and the software was installed on computers for student use. Students can work at their own pace, receive a tutorial, complete practice problems and a quiz. An independent t test was used for data analysis and the results demonstrated that there was no statistically significant difference between the two groups $t(47.699) = -.560$, $p = .578$). The author made an interesting point that if there was no significant difference, then the two treatments were equally effective as the means increased by 11.25 points for the teacher directed activity, and 9.96 points for the computer assisted instruction. However, the standard deviations of the two groups were indicated substantial variability. The teacher directed activity's standard deviation on the pre-test was 2.95, and with the computer-assisted instruction it was 2.62. However, post-test standard deviation for the teacher directed activity was 10.04, and computer assisted post-test standard deviation was 6.44. The author suggested that with such large variability in the standard deviations there may be additional factors interacting with the intervention. For instance, the computer assisted instruction does not provide that capability; it is impersonal. However, the teacher directed instruction is provided by a human who could sense student emotion, create a connection, provide explanations or reframing the directions or re-state the explanation.

Belland, Walker and Kim (2017) conducted a Bayesian network meta-analysis of 56 studies regarding computer-based scaffolding, addressing the need to measure the within subject magnitude of growth, using Hedges' g calculation, found that the greatest effect size was with students with learning disabilities (g = 3.13), in the subject of mathematics (g =1.29), and with project-based learning (g = 1.21). To understand Hedges' g, it is interpreted in the same manner as Cohen's d. An effect size of 0.2 is considered small, 0.5 is medium, and 0.8 is large. Hence, the effect sizes reported in this study are very large. Further, the study reports that the average annual gain of computer-based scaffolding were above average for middle school students. The authors conclude that computer-based scaffolding, as evidenced by the large effect sizes, can improve the learning outcomes of students with disabilities.

Technology in mathematics using IXL software. A case study (Stobaugh, Chanlder & White, 2015) of a high school in Kentucky that integrated IXL Math into its Response to Intervention (RTI) program reported a dramatic turnaround of the school. Tier 2 and 3 students, including those with special needs, used IXL Math four times per week. Within two years, the school increased from being the bottom 5 in state-wide ranking to the 97th percentile in achievement. The study authors attributed Differentiated Instruction, including the use of IXL Math, and a committed use of RTI to demonstrate "widespread improvement at the school level and in individual student gains" (Stobaugh, Chandler & White, 2015).

A recent doctoral dissertation on IXL analyzed its impact on learning outcomes (Arms, 2019). A small sample size of 97 7th grade students in Lafayette, Indiana participated in a short 12-week study comparing proficiency levels on pre- and post-assessments on a treatment group that completed IXL with a control group that did not. The students in the control group completed publisher- and teacher-made worksheets. Using a three-way ANOVA on socio-economic status, gender and IXL usage, this quantitative, quasi-experimental design, concluded that there is no statistically significant interaction between the treatment, gender or socio-economic status and their respective proficiency growth, $F(1, 89) = .60$, $p = .44$, on NWEA MAP Growth Assessments. Although the proficiency level was slightly higher for students using IXL (5.33) than those completing paper assignments (3.67), due to the insignificance of the statistical result, and the fact that both groups demonstrated growth, suggests that what teachers are doing in the classroom and the instructional practices they employ truly have a positive impact on learners' proficiency.

Copeland and Beach (2014) conducted an ex post facto, descriptive, causal-comparative study to determine if a significant difference exists in mathematical achievement of 3rd grade students between two different digital learning systems: Odyssey (Compass Learning) and IXL. Both systems offer personalized learning by allowing students to work at their own pace, while providing immediate feedback to students as they progress through the material working towards mastery. Both online programs are aligned to the Common Core Learning Standards. The instrument used to compare mathematical achievement was the Tennessee Comprehensive Assessment Program (TCAP), the state's summative assessment to measure student academic growth.

The sample consisted of 76 third grade students in a Title 1 elementary school which was identified by the state as a school that has large achievement gaps between the highest and lowest performing students.

The research design included two cohorts: an IXL condition group consisting of 37 students (22 males and 15 females) in academic year 2011-12, and the Odyssey condition group comprised of 39 students (18 males and 21 females) in academic year 2012-13. Further, the sample was divided into low and high ability based on prior years' TCAP scores for each of the conditions. Using one-way ANOVA, the results indicated a statistically significant difference existed between the two systems demonstrating that Odyssey (Compass Learning) had a positive influence on student mathematical achievement with respect to scores on the TCAP assessment, $F(1,68) = 9.901$, $p = .004$, vis-à-vis IXL. Although both digital learning systems had a positive impact, Odyssey (Compass Learning) was more effective than IXL in improving mathematical achievement, there was no significant difference between gender or by different abilities. Copeland and Beach concluded their study by stating the following, "The study found that integrating Odysseys (Compass Learning) in conjunction with teacher lead mathematics instruction improved student achievement and helped students meet math performance standards" (p. 1748). The research suggests that digital learning systems have potential for increasing student mathematical achievement.

Schuetz, Biancarosa and Goode (2018) conducted a quasi-experimental study in the spring of 2015 of the impact of technology on early elementary math student's math achievement. The study compared the results of IXL math intervention with a paper and pen control condition of 93 students in second grade. Two pre-test achievement scores and one engagement pre-score using the Likert-scale Math Interest Inventory were averaged together with equal weights for each student before the treatment began. The students were assigned to one of two groups for four weeks, and both groups experienced the same treatment and control conditions. Although there was no statistical difference in achievement between the treatment and control groups, the authors reported that the data from the teacher focus group points towards IXL as having greater levels of engagement and independence among young learners. Teachers reported that IXL provided them greater ability to differentiate and to scaffold more effectively, allowing advanced students to work at their own pace and with more challenging problems, while teachers assisted and supported those who struggled with the content.

Limitations of Educational Technology Use in Mathematics Instruction

There are many effective instructional strategies that do not require technology. The nine effective instructional strategies identified in research reviews that yield higher student achievement are: identifying similarities and differences, summarizing and note-taking, reinforcing effort and providing recognition, homework and practice, nonlinguistic representations, cooperative learning, setting objectives and providing feedback, generating and testing hypotheses, cues, questions, and advance organizers (Marzano, Pickering & Pollock. 2001). Additional non-technological instructional strategies that yield positive outcomes are Think-Puzzle-Explore, Chalk Talk, The 4C's, (Ritchhart, Church, & Morrison, 2011). Research (Kitchens, 2012) has shown that a simple instructional strategy like "Cover, Copy, Compare" is a very effective way to increase mathematical achievement with basic computational facts in younger students.

While technology is embraced as important to the teaching of mathematics, it cannot do it alone; the technology does not replace the teacher. Teachers and technology work together for the benefit of all students (Pane, 2018). Evidence that traditional instructional practices may play a greater role than computer assisted instruction in improving student outcomes comes from a best-evidence syntheses conducted by Slavin and Lake (2008). The authors summarized a total of 87 studies and the effect sizes of (a) changes to Mathematics Curricula, (b) supplementing instruction with Computer-assisted Instruction (CAI), and (c) improving Instructional Process Strategies on student achievement in elementary schools. There were 13 studies for Mathematical Curricula (ES = +0.10), 38 studies evaluated for CAI (ES = +0.19), and 36 studies included for Instructional Process Strategies (ES =+0.33) (Slavin & Lake, 2008.) While there were positive results on program outcomes with every study comparing treatment and control groups, the analysis demonstrated that improvement to Instructional Process Strategies had the greatest effect on achievement. Further, in an update to this study, Slavin, Lake and Goff (2009) conducted another best-evidence synthesis of 100 studies in middle and high schools and reported that the effect size for Cooperative Learning, one of several instructional process strategies, was higher than the median for middle school students (ES = +0.38). The conclusion of both these studies is that what teachers do in the classroom to keep students engaged and motivated is a major contributing factor to their success with mathematics. Technology alone does not improve student learning outcomes.

A meta-analysis study using mixed effects analysis of 74 studies with a sample size of 56,886 K-12 students reviewed three types of educational technology, Computer-

Managed Learning, Comprehensive Models and Supplemental Computer-aided Instruction. It concluded that educational technology offers a positive, but small effect (Cheung & Slavin, 2013). Of the three, Supplemental Computer-aided Instruction resulted in the greatest effect size. The authors interpreted the finding that supplementing traditional instruction with educational technology is beneficial, and what teachers must decide is how to best integrate applications into classroom setting to improve student achievement (Cheung & Slavin, 2013).

Technology-based Homework Support

The treatment under investigation in the present dissertation is the assignment of IXL learning activities in mathematics to be completed by students as homework, therefore it is relevant to examine the effectiveness of homework on academic achievement. Cooper, Robinson and Patall (2006) conducted a meta-analysis of 4,400 articles published from 1987 to 2003 that examined the homework-achievement relationship in K-12 schools. It was clear from the analysis that not all teachers assigned the same amount of homework to students, and that not all students completed the homework. This suggests that the level of achievement would be different for each student, as the level of achievement is dependent upon how much homework is assigned by the teacher, or how much is completed by the student. The meta-analysis divided the articles into three research design types: 1) Homework versus non-homework treatments, 2) Naturalistic, cross sectional measures regarding the amount of time students spent completing homework, coded by student or parent report measures, and 3) Simple bivariate correlation between student time completing homework and achievement measures, including coding for gender, socio-economic status and learning disability status. For the first research design type, the overall result indicated with a 95% confidence interval that there was a positive effective size (d = .39 to .97) on achievement outcomes for students completing homework. Students completing homework versus students not completing homework performed significantly higher on unit tests. Regarding the second research design type, cross-sectional measures, using data from the National Educational Longitudinal Study, every study reported positive and significant results with respect to regression coefficients. With respect to the third research design type, from the 50 of the 69 correlations, the amount of time students spends completing homework and achievement, the analysis found an average unweighted correlation of r = .14 indicating a positive, but weak relationship conducted for students in the junior high school level. The present research study will conduct and analysis between the achievement levels of the New York State Math exam scale scores and student utilization rate of IXL, the number of questions completed, and the number of skills mastered.

Although in each of the three research designs within the meta-analysis there was clear evidence of a homework-achievement relationship, the authors provide caution to conclude the existence of a causal relationship between the two. One reason may be that accomplished, motivated students may spend more time on task and work harder to complete homework. Hence, they achieve higher scores on assessments. This understanding is vital because, as the authors note it, is necessary for homework policies and practices to support that students receive the "optimum educational benefit" (Cooper, et al., 2006, p. 3.). It is critical therefore that educators design more high quality and educationally valuable assignments that are meaningful and purposeful with respect to the learning outcomes, and for the advantage of the student to maximize conceptual understanding and skill development.

Another study also examined online mathematics homework and its impact on student achievement, except this one focused on timely feedback that the student receives. One of the key issues of the study was utilizing formative assessment data relative to student performance and making instructional modifications to address student needs. Roschelle, Feng, Murphy, and Mason (2016) analyzed 2,850 7th grade math students from 43 schools in Maine, USA. This study was a randomized experiment where students were placed in either a treatment group of using the ASSISTments online software, or to a control group competing homework in the business as usual method. The incoming measurement was the New England Common Assessment Program (NECAP) test for reading and math. The outgoing measurement was the TerraNova Common Core assessment. The ASSISTments software offers over 300 topics for teachers to assign. These are called "skill-builders" and the purpose of assigning math homework is to provide students an opportunity to practice. With respect to data driven decision making, the ASSISTments tool provides a reporting feature for teachers to use to easily access student data. Professional development was provided to build teacher capacity to fully access the reports, to understand its meaning and to operationalize student performance data with differentiated instruction. This was accomplished with teachers either re-teaching certain topics to the whole class or personalizing instruction by assigning specific topics to small groups of students. Using a hierarchical regression model (HLM) the authors reported that the adjusted mean of the TerraNova scale scores of the treatment group, those using the ASSISTments software were 8.84 points higher than the control group, and significantly significant t(20) = 2.992, p = .007 (Roschelle., et al., 2016).

Researchers conclude that online mathematics homework coupled with teacher professional development focused on teachers' use of the system's reporting capabilities, and through this effort adapting their teaching practice, including providing immediate and personalized feedback, has a positive impact on mathematics achievement. The above study demonstrates the need for teachers use educational technology with its reporting capabilities to understand students learning needs, and with data-driven instruction meet them where they are in terms of their academic levels.

Mahmood (2017) examined the types of homework feedback and its impact on student mathematical achievement, with a focus on the implementation of the homework features of the IXL program. Over the course of an eight-week period, 59 8th grade students from 2 classes in a New York City school in the Spring of 2016-17 school year, from diverse backgrounds, all entitled to a free lunch, were randomly assigned to one of four homework feedback conditions. The four conditions were: 1) IXL computer-based homework with immediate feedback, 2) paper-pen homework with no feedback, 3) paper-pen homework with ability-based feedback, and 4) paper-pen feedback with effort-based feedback. Ability-based feedback is focused on the student, whereas effort-based feedback is focused on the task. The students would cycle through each of the feedback types every two weeks.

All students demonstrated an improvement in pre-post mean comparisons on the New York State Mathematics assessment, with IXL computer-based feedback and No feedback tied for lowest improvement at 3.5-point increase. Ability-based feedback was a 4-point increase, and effort-based feedback was a 6.4-point increase. Female students demonstrated the highest improvement with effort-based feedback with a 9.2 point-increase. Using repeated measures of Analysis of Variance (ANOVA), the study did not find a statistically significant relationship to feedback types, or by gender, and math achievement. $F(2.71, 157.15) = 0.38$. $p = 0.75 > 0.05$. A computer cannot provide effort-based feedback, and this result points to the value of a living entity – the teacher – as being the most vital aspect to student learning and generating positive academic results.

Professional Development and Use of Educational Technology

Professional development is vital to effectively using technology in the classroom, and data is most valuable when it informs teachers of areas of student's strength and critical need. However, the ability of teachers to collect student data, interpret it in meaningful way, and to use it productively is often a challenge (Dam, et al., 2018). However, Dam et al. (2018) identified several problems with professional development efforts as it relates to data driven decision making. The first problem is the time constraints and technical difficulties teacher face to collect data. The second is teachers having trouble understanding the data, especially with knowing how to use it to improve learning outcomes. The third challenge is teachers not having enough knowledge about how to effect change successfully to their pedagogy.

A major roadblock to technology utilization in the classroom is teacher's integration to support their pedagogy (Knight, 2012). Using a survey of 105 teachers in three small schools in Philadelphia, the correlational study regarding teachers' integration of technology in the classroom concluded that it was a function of their use, knowledge and perception of technology. But the converse may also be true; the less one knows about technology, the less one is to use it which may be detrimental to student learning. This may be because technology changes so fast it is difficult for anyone to keep pace with it. To effectively promote greater utilization of educational technology in the classroom, more professional development is required on an ongoing basis.

Using an extensive case study analysis regarding student data and professional development, Dam, Janssen and van Driel (2018) examined the use of a quality improvement method called PDCA (Plan-Do-Check-Act) and its impact on teacher practice. The PCDA quality improvement method requires teachers to plan a lesson and establish learning goals for students (Plan), teach the lesson (Do), collect data and compare outcomes to expectations to determine success (Check), and lastly, adjust instruction accordingly (Act.) Throughout the PDCA cycle, two key reflection questions emerged: (a) Did the student data meet expectations? and (b) Which change to instruction improved student outcomes? (Dam, et al., 2018). The authors concluded that teachers were able to increase their assortment of teaching strategies by positively experiencing the quality improvement and data decision making process. No longer was data being collected for the purpose of student accountability, but rather being done to support teacher learning; teachers learning about student learning needs. Further, teachers persisted in their development to make lessons and student learning more successful. It was demonstrated that not only did students increased their independence and self-regulation of learning; their thinking skills were enhanced as they asked questions more deeply. The findings of this study show that not only did the quality improvement method overcome teacher resistance to professional development, but also enhanced teacher professionalism and expertise, and changed their teaching practices to improve learning outcomes, as they and their students experienced success.

An ambitious study prepared for the Institute of Education Sciences, U.S. Department of Education, evaluated a professional development program designed to help teachers use data driven instruction, and its effects on teacher practice and increase student achievement (Gleason, et al, 2019). The professional development consisted of providing data coaches, support from school leaders for time and resources to analyze data, and collaboration with colleagues to interpret data and select appropriate instructional strategies. The experimental research was conducted in 12 districts comprised of 102 schools from eight states comparing achievement scores on interim and summative Smarter Balanced Assessments. There was a sample size of 12,535 4th and 5th grade students, and a teacher sample size of 470, of which were randomly assigned in mixed pairs to either the treatment or control groups.

A simple system of looking at student work was devised to determine obstacles to mastery. If student work was deemed "proficient", it was grouped into green category. If the work was deemed "approaching proficient it was coded yellow, and if "below proficient", it was labeled as red. Using these categories, teachers would select an evidence-based instructional strategy to address learner needs. Out of the five evidence-based instructional strategies considered, the most often chosen were: 1) small group instruction and 2) maximum instructional time on task. Surprisingly, using t-tests to compare samples, the study found that there was no significant difference in teacher utilization of data in instructional practice, nor was there an improvement in student achievement.

While greater and extensive professional development support was provided, one of the largest obstacles cited by the authors was there was insufficient time allotted for teachers to analyze student data and to collaborate regarding evidence-based instructional strategies. It was revealed that treatment schools met only about once per month to understand instructional needs of students and spent an equal amount of time as control schools on data analysis and collaboration. Therefore, school leaders must provide additional resources, perhaps by allotting more common planning time for data analysis. Another obstacle was teachers' selection of the instructional strategy. The authors argued that "more expert input into which instructional strategies would be most effective for them in light of their student data" (p. 54). Consequently, greater feedback by school leaders in how teachers select their instructional practices to address student needs may be necessary.

School leaders must also understand how teachers learn and find opportunities to support various modes of professional development. Jones and Dexter (2014) conducted a qualitative study of math and science teachers in two middle schools. Three types of professional development programs were explored. The first was a formal "Professional Learning Community" (p. 368) where the training activities were organized by the school or district. This is conducted to promote the organization's goals. The second was informal "Communities of Practice" (p. 370) where a working group of colleagues would meet to share information and solve problems. This is usually promoted by what was taught in the formal setting. The third type was independent called "Personal Learning Networks" (p. 3721) where individuals take their own initiative to learn. This may or may not have any connection with the organization's objectives. This case study of two middle schools comprised of 6th, 7th and 8th grade students utilizing focus groups and interviews of teachers examined how they obtain their information and share their knowledge about educational technology integration.

The findings suggest that a major barrier to teachers' learning about technology was scheduling conflicts and unclear alignment to practice. Teachers were more comfortable with an authentic presentation done by another teacher who was familiar with the technology. It was reported that formal sessions provided exposure and context. Prompted by the shortcomings of formal sessions, informal meetings allowed teachers to get their needs met by providing just-in-time support to fill in the knowledge gaps of formal training. Independent learning was most often conducted with a Google search; it was efficient and allowed creativity to thrive based on areas of teacher interest. The authors conclude that one professional learning approach supports the other, and that each approach must be supported. Leaders must not only focus on formal professional development, but also must foster opportunities from informal and independent learning to occur.

Lastly, ongoing and sustained professional learning activities, combined with educational technology, can lead to increased student mathematical achievement. A two year-long study of 1,263 8th grade students whose teachers experienced the MathForward professional development program offered by Texas Instruments measured the increase in achievement on the State of Texas Assessments of Academic Readiness (STARR) summative assessment. (Bicer & Capraro, 2017). The treatment consisted of extensive and long-term professional development 48 hours of professional development time to learn about the technology and incorporate it into their teaching practice. Also, teachers were provided with 3-hour common planning times once per week to share personal experiences and instructional strategies with their colleagues. Lastly, teachers were urged to work together with mathematicians to improve their content knowledge as they work to blend the technology into their instruction.

The results are quite promising! Using a repeated measures ANOVA, the authors found that the increase in students' mathematics scores of teachers who underwent the professional development intervention was statistically significantly improved ($p < .05$) from 7th to 8th grade, with a Cohen's d effect size equal to 0.26. With respect to gender, both males and females STAAR scores were statistically significantly improved ($p > .05$) from 7th to 8th grade, with a Cohen's d effect size equal to 0.28 for females and 0.26 for males. For ethnicity, White and Black students increased their math scores in a statistically significant manner ($p > .05$) from 7th to 8th grade, with a Cohen's d effect size equal to 0.25 for White students and 0.31 for Black students. Regarding special needs status, IEP and non-IEP STAAR scores were statistically significantly improved ($p > .05$) from 7th to 8th grade, with a Cohen's d effect size equal to 0.46 for IEP students and 0.28 for non-IEP students. Clearly, the amount of professional development afforded to teachers had a significant and positive impact on the achievement on their students.

Summary of Literature Review

The purpose of this study is to evaluate the effectiveness of IXL Math online software in raising student achievement on the New York State Math exam, with special focus on effects by student gender, ethnicity and disability status. Chapter 2 reviewed the literature pertaining to the analysis of educational technology on student mathematical achievement. The literature review revealed that educational technology can enhance mathematical achievement through increased understanding of math concepts (Zengin, 2016) and diverse populations of students can succeed using online systems (Gatti, 2013). However, small to moderate effects can be attained using computer assisted instruction (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Of the various pedagogical approaches considered, immediate feedback was most effective on learning outcomes in a computer-based setting. (Van der Kleij, Feskens & Eggen, 2015).

Educational technology can increase motivation and create positive attitudes in students, thereby increasing the potential for higher mathematical achievement (Higgins, Huscroft-D'Angelo & Crawford, 2017). Several math online programs have demonstrated statistically significant increased achievement in math (Bennet, 2010; Brasiel, Jeong, Ames, Lawanto, Yan & Martin, 2016) while others have not (Pellegrini, Lake, Inns, & Slavin, 2018). Although, educational technologies that accentuate personalization, engagement, and motivation have the most impact on mathematics instruction.

However, no statistically significant difference has been attributed to gender and mathematical achievement (Hatfield, 2019). Yet, female students out-performed male students in both computer-assisted and traditional instructional environments (Spradlin & Ackerman, 2010). Further, gender differences exist in terms of perceptions of using technology (Vale & Leder (2004). Although, there was no statistical difference between genders with respect to using IXL as an intervention (Brown, 2018), there were differences reported with various other educational packages (Feng, Roschelle, Mason & Bhanot, 2016).

Regarding ethnicity, the research demonstrates that educational technology can help to close the achievement gap by meeting the individual needs of students (Huang, Craig, Xie, Graesser, Okwumabua, Cheney & Hu, 2013), and it has been shown that increased utilization rates of online software are positively correlated with improved mathematical achievement (Ahn, Beck, Rice and Foster (2016). Additionally, Hispanic students, especially those who have immigrated to the United States later in their lives can benefit from educational technology (Park, Lawson and Williams, 2012)

Lastly, computer-assisted instruction can improve the problem-solving skills of students with learning disabilities, (Xin, Tzur, Hord, Liu, Park & Si, 2017) However, the variability in results between traditional instruction and computer assisted instruction point towards a greater need for human interaction for students with special needs (Stultz, 2013). Interestingly, educational technology has the potential to bring about the most improvement in math achievement for students with special needs through computer-based scaffolding (Belland, Walker and Kim, 2017).

IXL has demonstrated mixed results in terms of raising student mathematical achievement. When used with differentiated instruction and Response to Intervention IXL provided dramatic positive results (Stobaugh, Chanlder & White, 2015) whereas another study reported no statistically significant interaction between the treatment, gender or socio-economic status and their respective proficiency growth (Arms, 2019). However, IXL, when compared with another educational technology product, while there was no statistical difference in producing increased achievement, both digital learning systems had a positive impact in improving mathematical achievement (Copeland and Beach, 2014). Importantly, IXL offers educators greater ability to differentiation lessons and to provide scaffolding to struggling students, and for those more accomplished to work on more challenging topics; allowing both students to work on their own level and at their own pace. (Schuetz, Biancarosa & Goode, 2018)

Regarding the relationship between homework completion and achievement outcomes, there is a positive effect size on achievement for students completing homework, and educators must recognize the different motivational levels of accomplished versus struggling students to complete homework (Cooper, Robinson and Patall, 2006). One of the features that makes homework effective, is its timeliness of the feedback that the student receives. In addition to the system providing feedback directly to the student, teachers using the reporting capabilities of educational technology can personalize instruction by providing immediate feedback and assigning specific topics to individual students (Roschelle, Feng, Murphy, and Mason, 2016). Lastly, the type of feedback can have an influence on achievement. Although computers strive to emulate human-type feedback, the technology is still impersonal. The human teacher has the unique ability to offer empathy, support and encouragement and provide what research has shown to be the most effective feedback – effort feedback (Mahmood, 2017).

With respect to professional development, the literature review provides evidence that the obstacles to teachers improving their instruction can be overcome with a systemized training; one that is practical and easy to implement in their practice. (Knight, 2012) As they experience the positive effects of their efforts on student success, they will adapt to change and adopt new methodologies (Dam, et al., 2018). This in turn may translate into student growth. Also, instructional leaders must provide greater time for teachers to gather and analyze student data, and to collaborate with colleagues about selecting appropriate instructional strategies to meet the learning needs, and to close knowledge and skill gaps (Gleason, et al, 2019). School leaders must also acknowledge the various methods in which teachers learn, especially as it related to educational technology, and foster an atmosphere where educators have time to meet, collaborate and explore while meeting the goals of the organization and increasing student achievement (Jones and Dexter, 2014).

Lastly, profession development that is long-lasting, and focused on educational technology that is combined with evidenced-based instructional strategies holds great promise to improve the mathematical achievement of students of all types. (Bicer & Capraro, 2017). As teachers become more proficient with the software their ability to positively impact achievement can increase. Students' increased achievement would provide teachers a source of encouragement to continue learning, sharing information and experience, as well as, data-mining and re-teaching as they experience greater success with online instructional programs. Finally, a commitment to continuous professional learning regarding the utilization of educational technology can contribute to improving student achievement.

The present study of IXL's impact on student mathematical achievement expands on the existing body of knowledge in several ways. First, it is long-term in nature. Unlike other studies that were conducted for a duration of a few weeks or months, the present study is conducted over a full academic year comparing the Non-IXL cohort to the IXL cohort over 10-month time-span. Second, unlike other studies that examine only one grade (e.g. 6^{th} grade), the present study analyzes a complete middle school 6^{th}, 7^{th} and 8th grades. Third, the present study not only reviews subgroups of students (gender, ethnicity and special need status), but also analyzes the relationship of utilization (time spent completing IXL homework), number of questions answered, and number skills mastered on mathematical achievement. Lastly, it is the only study of its kind working in collaboration with CUNY's Early College Initiative to understand how the impact of educational technology in general, and IXL in particular, coupled with excellent pedagogy, can help make the students of New York City college and career ready.

CHAPTER 3

Methods and Procedures

The purpose of this study was to evaluate the effectiveness of IXL Math online software in raising student achievement on the New York State Math exam, with special focus on effects by student gender, ethnicity and disability status. Chapter 3 details the hypothesis and research questions that the study will analyze and answer in later chapters. This chapter will provide a description of this study's research design study, offer a narrative of the data analysis with various tests to be conducted using SPSS software, and provide descriptive statistics of the sample population. Additionally, this chapter will review the instruments that are used for analysis along with their tested items, as well as an explanation of the exam validity, and scoring accuracy. After that, a description of IXL Math's utilization, SmartScore determination, and student login authentication will be discussed.

Hypotheses

This research study will test the following null hypotheses:

1. There is no significant difference in means on the NYS math exam between IXL-Math cohorts and Non IXL-Math cohorts
2. The is no significant difference in means on the NYS Math exam of males and females between IXL-Math cohorts and Non-IXL Math cohorts
3. The is no significant difference in means on the NYS Math exam of socio-economic status between IXL-Math cohorts and Non-IXL Math cohorts
4. There is no significant difference in means on the NYS Math exam of ethnicities between IXL-Math cohorts and Non-IXL Math cohorts

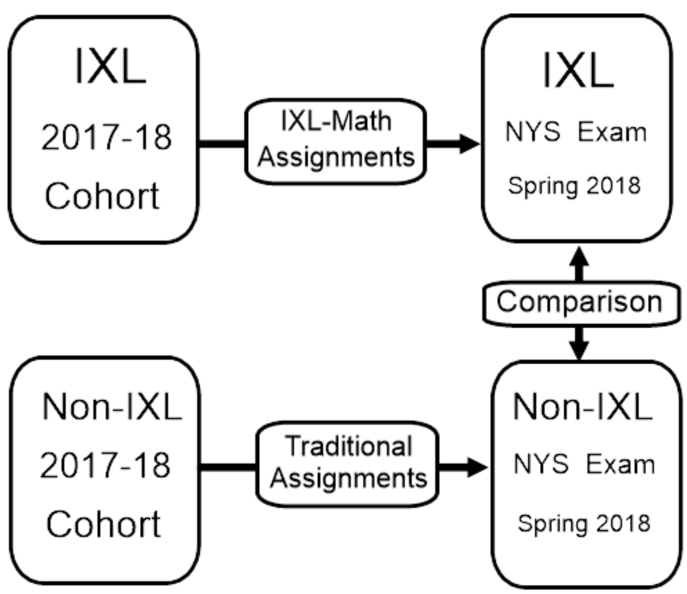
5. There is no significant difference in means on the NYS Math exam of students with disabilities between IXL-Math cohorts and Non IXL-Math cohorts.
6. There is no direct positive correlation between IXL usage, questions completed, and standards mastered and assessment performance.

Research Design and Data Analysis

Research design. A quasi-experimental study was conducted comparing NYS Exam data between a control group of 6^{th}, 7^{th} and 8^{th} grade students not exposed to IXL Math, and completing traditional assignments in academic year 2017-18 (Non-IXL Cohort) with a treatment group 6^{th}, 7^{th}, and 8th grade students who used IXL Math in academic year 2017-18 (IXL Cohort.) Both samples are from the same urban district.

Figure 2**.**

Research Design Comparing IXL-Math Cohort and Non-IXL Math Cohort



Data analysis. The data will be organized to relate to each corresponding student in an Excel spreadsheet and imported to SPSS for descriptive and statistical analysis. The following tests will be run with respect to each hypothesis:

a. Independent Samples t-test will be run to determine statistically significant difference in the means between the means of IXL-Math and Non-IXL Math Cohorts.

a. Two-way Analysis of Variance will be used to determine statistically significant difference between IXL-Math and Non-IXL Math cohorts and gender (male and female) and Math exam scores.

b. Two-way Analysis of Variance will be used to determine statistically significant difference between IXL-Math and Non-IXL Math cohorts and ethnicity (4 groups: Black, Hispanic, Asian, White) and Math exam scores.

c. Two-way Analysis of Variance will be used to determine statistically significant difference between IXL-Math and Non-IXL Math cohorts and disability (students with and without disabilities) and Math exam scores.

d. Pearson's Coefficient will be used to determine if there is a relationship between Math exam scores and IXL usage, questions completed, and standards mastered.

Sample or Participants

The sample for the dissertation consists of data gathered from over 230 6th, 7th, and 8th grade students in each cohort (IXL and Non-IXL) from two Title 1 middle schools in the same district of the urban setting. A description of the demographics of each cohort is as follows:

IXL-Math Cohort – There are 236 6th, 7th and 8th grade students from the 2017-18 academic year. It is comprised of 47.5% female and 52.5% male. In terms of ethnicity, it is comprised of Asian – 9.7%, Black – 27.1%, Hispanic – 33.5% White – 29.7%. The percent of students with disabilities is 20.0%, and the percent of students without disabilities is 80.0%. The percent of students with a socio-economic status of poverty is 80.0% and the percent of students not of poverty is 20.0%. (Table 7.)

Non-IXL Math Cohort –_There are 232 6th. 7th and 8th grade students from the 2017-18 academic year. It is comprised of 48.3% female and 57.7% male. In terms of ethnicity, it is comprised of Asian – 10.3%, Black – 24.6%, Hispanic – 34.4% White – 30.6%. The percent of students with disabilities is 23.7%, and the percent of students without disabilities is 76.3%. The percent of students with a socio-economic status of poverty is 77.2% and the percent of students not of poverty is 22.8%. (See Table 8.)

Table 8.

Student Composition of IXL-Math Cohort and Non-IXL Math Cohort

	IXL-Math Cohort, n = 236		Non-IXL Math Cohort, n = 232	
Characteristic	Number	Percent	Number	Percent
Male	124	52.5%	120	51.7%
Female	112	47.5%	112	48.3%
Asian	23	9.7%	24	10.3%
Black	64	27.1%	57	24.6%
Hispanic	79	33.5%	80	34.4%
White	70	29.7%	71	30.6%
With Disability	47	20.0%	55	23.7%
Without Disability	189	80.0%	177	76.3%
Poverty	189	80.0%	179	77.2%
Non-Poverty	47	20.0%	53	22.8%

Instruments

New York State math exam. The purpose for the New York State test in mathematics in 6th, 7th and 8th grades is to measure student knowledge and skills as defined by grade-level New York State Common Core Learning Standards (CCLS) in Mathematics. (NYSED, 2018). New York State public school students in grades 3 through 8 complete a non-mandatory mathematics assessment completing multiple choice questions as well as, short and extended response type questions covering the major clusters in each grade. The information summarized below is presented in the Technical Manual (Questar, 2018) for the examination, available at http://www.p12.nysed.gov/assessment/reports/ei/tr38-18w.pdf

Tested items. The test is comprised of Major, Supporting and Additional clusters. Major clusters represent the most important topics of the grade and are the emphasis of teaching and testing which account for the majority of test questions. According to EngageNY (2018), "Major clusters are areas of intensive focus, where students need fluent understanding and application of the core concepts (approximately 70%.)" In addition, the test includes items from Supporting clusters which includes "rethinking and linking; areas where some material is being covered, but in a way that applies core understandings (approximately 20%) (EngageNY, 2018) and Additional clusters which "expose students to other subjects, though at a distinct, level of depth and intensity (approximately 10%)" (EngageNY, 2018.)

The major clusters for 6th grade are: Ratios and Proportional Relationships, The Number System and Expressions and Equations. The Supporting cluster is Geometry, and the Additional Cluster is Statistics and Probability, as well as computing multi-digit numbers and finding common factors and multiples within the Number System.

The major clusters for 7th grade are: Ratios and Proportional Relationships, The Number System and Expressions and Equations. The Supporting cluster is Geometry, and the Additional Clusters are making inferences about two populations within Statistics and Probability and solve questions involving angle measure, area, surface area, and volume within Geometry.

The major clusters for 8th grade are: Expressions and Equations, Functions and Geometry. The Supporting clusters are: Number Systems, modeling relationships between quantities within Functions and Statistics and Probability and the Additional Cluster is Geometry and solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.

Exam validity. The validity of the Math exam was examined in two ways: Content Validity and Construct Validity. The content of the test is carefully matched with the Common Core Learning Standards. With respect to Content Validity, educators with experience in both teaching and testing were involved in the test development as well as the scoring rubric. This was intended in creating validity of the test and reliability in the test scores. The test development process with educators included: Item Development, Educator Item Review, Field-Testing, Range-finding and Final Eyes Committee.

An analysis of question items and their ability to measure the same type of skills and to provide high internal consistent values demonstrates evidence of Construct Validity. "For the total population, the mathematics reliability coefficients (Cronbach's alpha) ranged from .93 to .95, and for all subgroups, the reliability coefficients were greater than or equal to .80." (NYSED, 2018). Since Cronbach's alpha is greater than 0.7, the New York State Math exam offers excellent internal consistency and delivers rigorous construct validity.

Scoring accuracy. The scoring of NYS Math exams is done at several sites throughout the urban school district. The urban school, which was the site of the study, was scored in three separate locations. Each site employed Content Trainers who were trained by NYS according to a rubric, and each content trainer would turn-key the training received to train was used to train a scoring committee comprised of teachers for each grade. Scoring committee members were given a training guide, practice set and a consistent assurance set (CAS.) Content trainers would explain the scoring guide and review the various examples. When complete, the scoring committee members would work independently to score the practice set. After that, a review of the responses was conducted and then a norming process ensued. This was to ensure accurate application and fidelity to the rubric in the scores given by committee members. At the conclusion, a quality control process was conducted with the completion of the consistent assurance set. This process helped to determine the readiness of scorers to score exams and if a deficiency was noted, re-training would be offered to strengthen the ability of the scorer to score each exam accurately.

Treatment: IXL Math

IXL is an adaptive online program that provides a vibrant environment for students to learn math and to practice their skills while working towards mastery with a limitless quantity of individual questions. Students are assigned standards to complete by teachers and as they work the questions increase in difficulty. Should a student obtain an incorrect answer, the program offers an explanation as to the correct solution and provides a similar question for the student to try. When the student answers correctly, the program displays a congratulatory message, like “Great work!” or “Wonderful!” In addition, the system awards students with medals and other prizes. The immediate feedback keeps students engage and motivated to work and learn. Student motivation at the research site was promoted with completion charts posted on the classroom walls and periodic “Certificates of Excellence” were awarded to students.

Fidelity of implementation. Three different teachers were involved in using the IXL program, and each teacher assigned homework using the IXL online software for daily math practice. However, differences existed to the extent teachers used the system with respect to the number of topics assigned each night for practice. The researcher, as chairperson of the math department of the study site school, provided professional development to middle school teachers with assisting them to set up the class rosters, making skill assignments, obtaining student scores, tracking completion, printing certificates, and using the diagnostic tool. Although there was uniformity in teacher training, the researcher was not the teachers’ direct supervisor and could not hold teachers responsible for utilization in their classes. Due to individual teacher preferences, their comfort with the IXL Math system, their curriculum needs and choices, adaptation to online practice methods and differences in motivation methods used, variations in the utilization rate of the system may exist. This will be address in the limitations section of this chapter.

SmartScore. The SmartScore measures how well a student understands a skill and is based on IXL's exclusive formula. With the SmartScore, the learning process is rewarded, and students are regularly reevaluated. When students start practicing a skill, the SmartScore starts at zero. As students answer questions correctly, the SmartScore increases. If a question is answered incorrectly, the score decreases. However, the SmartScore is not based on the percentage of questions answered correctly. Rather, it is calculated using a proprietary algorithm to calculate several factors, including the number of questions completed, question degree of difficulty, and consistency of correct answers at a given level. The SmartScore progression (increasing and decreasing scores) are custom-designed for each skill based on the levels of rigor and cognitive demand of that skill. A skill is mastered when the SmartScore reaches 100, but the number of questions it takes to master a skill varies with every student. A score of 90 is proficient, and a score of 100 is considered mastery. (IXL Learning, 2018).

Once students reach a SmartScore of 90 and enter the Challenge Zone, they will need to answer a certain number of questions (as many as 10) correct in a row to reach mastery. The Challenge Zone includes the most rigorous questions for that skill and requires students to prove they have truly mastered the skill by answering those questions consistently. If a student misses a question in the Challenge Zone, their SmartScore will recalibrate to a more accurate level, which usually involves a decrease of 3-8 points. This ensures students have the chance to refine their skills and build back up to mastery. Students achieving skill mastery is an indication that he or she truly understands the skill. (IXL Learning, 2018).

Usage. The elapsed time students spend on the IXL system is called usage and is measured in minutes. A counter is built into the system to measure a user's elapsed time spent in minutes practicing a skill. It does not include, for instance, the amount of time that a child may spend signing in to and navigating IXL. The timer starts the moment a student begins a question, including time to read the question, calculate the answer, input an answer and receive feedback or to read an explanation if an incorrect answer was given. The timer ends the moment practice ceases with a student closing the session. The elapsed time excludes an idle time measurement of 6 minutes when inactivity is detected or a student navigates to a different section of IXL to view a reward status or search for a new skill to practice. Then, the timer stops and that idle time is not recorded. If the student is not actively practicing, because of taking a break or deciding to explore another area of the website, the timer pauses. When the student begins practice again, the counter resumes. The built-in timer records only the total amount of time a student devotes to actively completing assignments and practicing skills. This is to ensure that usage reports don't mistakenly report idle time as time spent practicing. According to IXL's teacher's user guide, the timer is an accurate measure of IXL practice. (IXL Learning, 2018).

In addition, the researcher made a written request to the IXL Learning research department for a "Performance Report" which detailed the student usage in minutes, number of questions completed, and number of standards mastered. The reported activity indicated the following: 45,312 hours, 17 minutes' time spent, 533,321 problems attempted, and 6246 skills mastered.

Student authentication. Students login the IXL system using an assigned Username and Password. These are comprised of non-public personal information. The students are directed in class how to login to IXL using this pre-ordained information. Users maintain the option of changing passwords and teachers have access to the information should a student have difficulty signing into the system because of a forgotten password. Additionally, IXL offers Google Single Sign that better ensures students are signing in to their own accounts. (IXL Learning, 2018).

Procedures for Data Collection

A formal proposal was submitted to the New York City Department of Education's Research and Policy Support Group for the demographic and achievement data of the control and treatment groups. A written request was submitted to IXL Learning Research Department for the IXL "Performance and Usage Report" which contained the Time Spent, Problems Attempted, and Skills Mastered for the treatment group. This usage file was sent to the Research and Policy Support Group, which removed all personal identifying information, scrambled the student identification numbers, and transmitted separate files via file transport protocol. The researcher merged the data files were together by matching the scrambled student indentation numbers, to create one file containing IXL and Non-IXL cohort demographic and achievement data. This file was imported and used for subsequent analysis in SPSS v 24.

Limitations

Threats to statistical conclusion. The threats to statistical conclusion are the following: low statistical power in that the sample size is small; and low reliability of treatment implementation in that multiple teachers decided how to best use the IXL system.

Threats to internal validity. The threats to internal validity was low reliability of treatment implementation. Regarding the implementation, there were multiple teachers involved in using the IXL program, and each teacher decided how and to what extent he or she wanted to use the program. Professional development was provided by the researcher with assisting teachers to set up the class rosters, making skill assignments, obtaining the scores, and tracking completion and there exists variations in how the system was used.

Threats to external validity. The threat to external validity is conducting a generalization across treatments. Since the treatment sample was from the Early College Initiative in a middle school in New York city, the inferences would not be applicable to high school students within the same geographic area, nor would they be applicable to students of different geographic areas that are not Title 1, urban and of diverse demographics.

CHAPTER 4

Results

Null Hypothesis 1: There is no significant difference in means on the NYS math exam between IXL-Math cohort and Non IXL cohort.

Independent Samples t-test was used to determine if there was a significant difference in the means of two unrelated NYS Exam Scale Scores between the IXL-Math (the treatment group) and Non-IXL (the control group) cohorts. The control group received traditional paper-based homework assignments and the treatment group received IXL-Math online software homework assignments.

Levene's Test of Equality of Variances was conducted, $F(466) = 1.24$, $p = .27$, and the assumption was satisfied because the p value ($p = .27$) was greater than the confidence interval ($\alpha = .05$), and therefore the variances were assumed to be equal. Accordingly, corresponding independent samples t-test output was used for analysis.

The results of the independent samples t-test were: $t(466) = 1.55$ $p = .12$, 95% CI [-6.83, 5.467]. In this analysis, the p value (.12) is greater than the alpha value (.05). This data suggests that the means of the IXL-Math and Non-IXL Cohorts are not statistically significantly different. The null hypothesis was rejected. The mean for the IXL cohort ($M = 596.19$, $SD = 16.18$) was not significantly different than that of the Non-IXL cohort ($M = 593.78$, $SD = 17.415$.)

Therefore, the scale scores, presented in Table 9, of the two cohorts (IXL and Non-IXL) did not differ significantly. Although the mean of the math scale scores of the IXL cohort was greater than that of the Non-IXL cohort, these findings demonstrate that using IXL Math online software was not more effective than Non-IXL traditional paper-based assignments.

Table 9.

Descriptive Statistics Comparing Math Scale Scores of IXL and Non-IXL Cohorts

	Cohort	N	Mean	Std. Deviation	Std. Error Mean
Math Scale Score	IXL	236	596.19	16.179	1.053
	Non-IXL	232	593.78	17.415	1.143

Null Hypothesis 2: There is no significant difference in means on the NYS Math exam by Gender (males and females) between IXL-Math cohort and Non-IXL Math cohort.

A two-way ANOVA was used to determine if there is a statistically significant difference in the math scale scores and gender (male and female) and cohort types (IXL and Non-IXL). The assumption of homogeneity of variances was tested using Levene's Test, F (3, 464) = 1.161, p = 0.32. Since the p value (.32) is greater than the alpha value (.05), group variances were assumed to be homogeneous.

The two-way ANOVA was conducted to compare the influence of two independent variables, Gender and Cohort, and the interaction effect between Gender and Cohort on math state exam scale scores. Mean scores and standard deviations for the subgroups are presented in Table 10, and results of the statistical tests are presented in Table 11. The main effect of Gender on math achievement (F(1,464) = 3.567, p = .06, η^2 = 0.008) indicated no significant difference between male (M = 593.61, SD = 16.609) and female (M =596.51, SD = 16.972) students. The main effect for Cohort type on math achievement ($F(1, 464) = 3.567$, $p = .12$, $\eta^2 = 0.005$) indicated no significant difference in using IXL (M = 596.19, SD = 16.179) or Non-IXL (M = 593.78, SD =17.415). Further, the interaction effect between Gender and Cohort ($F(1,464) = 0.141$, $p = .71$, $\eta^2 > 0.000$) yielded no significant difference. Alternatively stated, there was no significant interaction effect between Gender and Cohort for math scale scores.

Table 10.
Descriptive Statistics comparing Math Scale Scores by Gender and Cohort Type

Dependent Variable: Math Scale Scores

Gender	Cohort	Mean	Std. Deviation	N
Female	IXL	597.43	15.530	112
	Non-IXL	595.60	18.325	112
	Total	596.51	16.972	224
Male	IXL	595.08	16.727	124
	Non-IXL	592.08	16.416	120
	Total	593.61	16.609	244
Total	IXL	596.19	16.179	236
	Non-IXL	593.78	17.415	232
	Total	595.00	16.828	468

Table 11.
*Tests of Between-Subjects Effects for Gender, Cohort and Gender*Cohort*

Dependent Variable: Math Scale Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1722.289[a]	3	574.096	2.041	.107	.013
Intercept	165386347.800	1	165386347.800	587920.023	.000	.999
Gender	1003.431	1	1003.431	3.567	.060	.008
Cohort	680.379	1	680.379	2.419	.121	.005
Gender * Cohort	39.754	1	39.754	.141	.707	.000

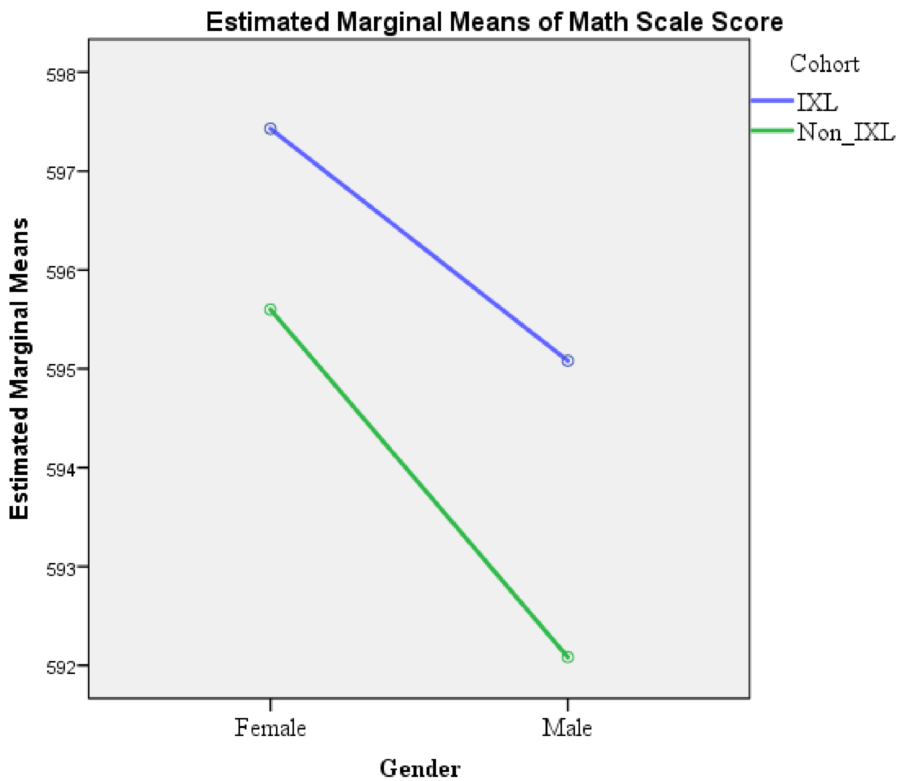
Table 11. (continued)

Error	130526.708	464	281.308
Total	165814759.000	468	
Corrected Total	132248.998	467	

a. R Squared = .013 (Adjusted R Squared = .007)

Figure 3.

Line Graph demonstrating Mean Scores relative to Gender and Cohort Type



Null Hypothesis 3: There is no significant difference in means on the NYS Math exam by ethnicity (Black, White, Hispanic, Asian) between IXL-Math cohort and Non-IXL Math cohort.

A two-way ANOVA was used to determine if there is a statistically significant difference in the math scale scores and student ethnicity (Black, White, Hispanic, Asian) and cohort types (IXL and Non-IXL) The assumption of homogeneity of variances was tested using Levene's Test, F (7, 460) = 1.235, p = .28. This means that the group variances were assumed to be homogeneous.

The two-way ANOVA was conducted to compare the influence of two independent variables, ethnicity and cohort, and the interaction effect between ethnicity and cohort on math state exam scale scores, presented in Table 12 and the results of the statistical tests are presented in Table 13. The main effect of ethnicity on math achievement (F(3,468) = 6.79, p < .001, η^2 = 0.42) indicated a significant difference among Black (M =592.21, SD =16.589), Asian (M = 597.49, SD = 16.750), White (M = 599.23, SD = 14.695) and Hispanic (M = 592.21, SD = 17.889) students. The main effect for Cohort type on math achievement indicated a (F(3, 468) = 3.709, p = .06, η^2 = 0.008) indicating no significant difference between IXL (M = 596.19, SD = 16.179) and Non-IXL (M =593.78, SD = 17.415). Further, the interaction effect between ethnicity and cohort (F (3,468) = 2.296, p = .77, η^2 = 0.015) yielded no significant difference. In other words, there was no significant interaction between ethnicity and cohort for math scale scores.

Post-hoc analysis, presented in Tables 14 and 15, indicates that there was significant difference in Black and Hispanic students' achievement on the Math exam relative to other ethnicities (White, Asian) with respect to IXL-Math treatment type. Black students performed below Asian (p = .03) and White (p <.001) students in the IXL treatment, and Hispanic (p = .01) students performed below White students in the IXL treatment.

Table 12.
Descriptive Statistics Comparing Scale Score by Cohort Type and Ethnicity

Dependent Variable: Math Scale Scores

Cohort	Ethnicity	Mean	Std. Deviation	N
IXL	Asian	601.78	15.333	23
	Black	590.55	15.181	64
	Hispanic	593.54	17.850	79
	White	602.51	12.543	70
	Total	596.19	16.179	236
Non-IXL	Asian	593.38	17.325	24
	Black	594.09	17.990	57
	Hispanic	590.94	17.945	80
	White	596.87	16.148	71
	Total	593.78	17.415	232
Total	Asian	597.49	16.750	47
	Black	592.21	16.589	121
	Hispanic	592.23	17.889	159
	White	599.67	14.695	141
	Total	595.00	16.828	468

Table 13.
*Tests of Between-Subjects Effects for Cohort, Ethnicity and Cohort*Ethnicity*

Dependent Variable: Math Scale Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8127.412[a]	7	1161.059	4.303	.000	.061
Intercept	132054096.100	1	132054096.100	489398.227	.000	.999
Cohort	1000.878	1	1000.878	3.709	.055	.008
Ethnicity	5496.041	3	1832.014	6.790	.000	.042
Cohort * Ethnicity	1858.246	3	619.415	2.296	.077	.015
Error	124121.586	460	269.830			
Total	165814759.000	468				
Corrected Total	132248.998	467				

a. R Squared = .061 (Adjusted R Squared = .047)

Table 14.
Pairwise Comparisons of Cohort and Ethnicity

Dependent Variable : Math Scale Score

Cohort	(I) ethnicity	(J) ethnicity	Mean Difference (I-J)	Std. Error	Sig.[b]
IXL	Asian	Black	11.236*	3.993	.031
		Hispanic	8.238	3.892	.209
		White	-.732	3.948	1.000
	Black	Asian	-11.236*	3.993	.031
		Hispanic	-2.997	2.763	1.000
		White	-11.967*	2.841	.000
	Hispanic	Asian	-8.238	3.892	.209
		Black	2.997	2.763	1.000
		White	-8.970*	2.696	.006
	White	Asian	.732	3.948	1.000
		Black	11.967*	2.841	.000
		Hispanic	8.970*	2.696	.006
Non-IXL	Asian	Black	-.713	3.997	1.000
		Hispanic	2.438	3.823	1.000
		White	-3.498	3.879	1.000
	Black	Asian	.713	3.997	1.000
		Hispanic	3.150	2.847	1.000
		White	-2.786	2.921	1.000
	Hispanic	Asian	-2.438	3.823	1.000
		Black	-3.150	2.847	1.000
		White	-5.936	2.678	.163
	White	Asian	3.498	3.879	1.000
		Black	2.786	2.921	1.000
		Hispanic	5.936	2.678	.163

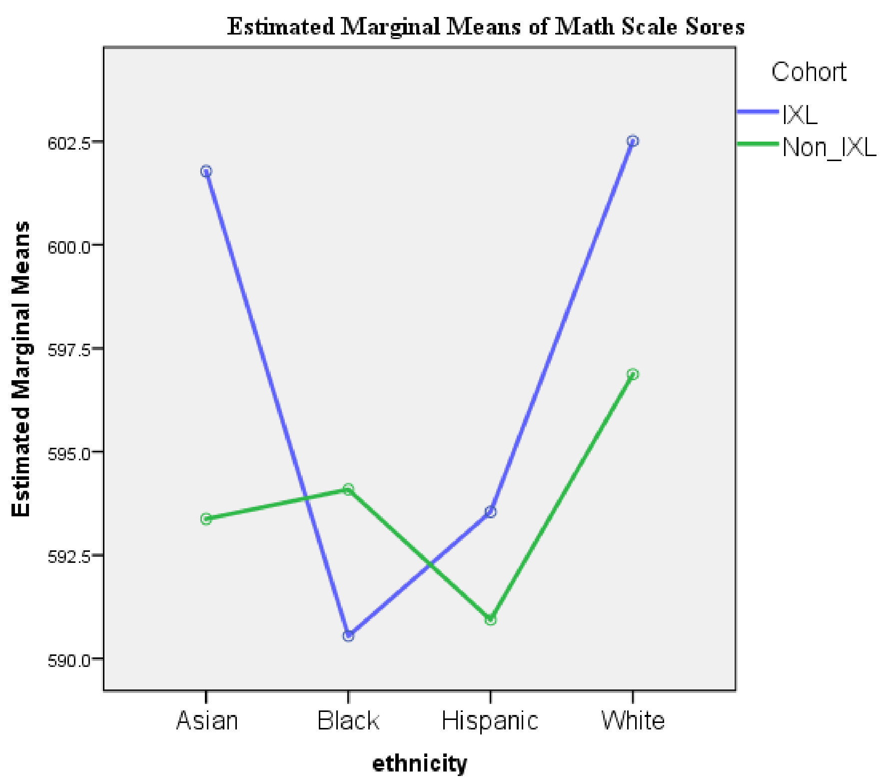
Table 15.
Post-Hoc Analysis Comparing Math Scale Scores by Ethnicity

Ryan-Einot-Gabriel-Welsch Range[a]

		Subset	
Ethnicity	N	1	2
Black	121	592.21	
Hispanic	159	592.23	
Asian	47	597.49	597.49
White	141		599.67
Sig.		.266	.769

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 269.830.
a. Alpha = .05.

Figure 4.
Line Graph demonstrating Mean Scores relative to Ethnicity and Cohort Type



Null Hypothesis 4: There is no significant difference in means on the NYS Math exam of students with disabilities between IXL-Math cohort and Non-IXL Math cohort.

A two-way ANOVA was used to determine if there is a statistically significant difference in the math scale scores and student IEP status (students with and without disabilities) and cohort types (IXL and Non-IXL). The assumption of homogeneity of variances was tested using Levene's Test, F (3, 464) = 1.752, p = .16. Since the p value is greater than the alpha value, the group variances do not differ significantly and were assumed to be equal.

The two-way ANOVA was conducted to compare the influence of two independent variables, disability status and Cohort, and the interaction effect between IEP and Cohort on math state exam scale scores, presented in Table 16 and the results of statistical tests are presented in Table 17. The main effect of disability status on math achievement ($F(1,464) = 26.79$, $p < .001$, $\eta^2 = 0.06$) indicated a significant difference between students with disabilities (M = 587.79, SD = 17.734) or without disabilities (M =597.01, SD = 16.024). The main effect for Cohort type on math achievement ($F(1, 464)$ = .549, p = .46, $\eta^2 = 0.001$) indicated no significant difference in using IXL (M = 596.19, SD = 16.179) or Non-IXL (M = 593.78, SD =17.415). However, the interaction effect between IEP and Cohort (F (1,464) = 11.013, p = .001, $\eta^2 = 0.023$) yielded a statistically significant difference. In other words, there was a significant interaction effect between students with disabilities and cohort for math scale scores.

Table 16.

Descriptive Statistics Comparing Scale Scores by IEP Status and Cohort Type

Dependent Variable: Math Scale Score

Cohort	IEP	Mean	Std. Deviation	N
IXL	No	599.28	14.972	189
	Yes	583.81	15.010	47
	Total	596.19	16.179	236
Non_IXL	No	594.58	16.781	177
	Yes	591.20	19.253	55
	Total	593.78	17.415	232
Total	No	597.01	16.024	366
	Yes	587.79	17.734	102
	Total	595.00	16.828	468

Table 17.

*Tests of Between-Subjects Effects for Cohort, IEP Status and Cohort*IEP Status*

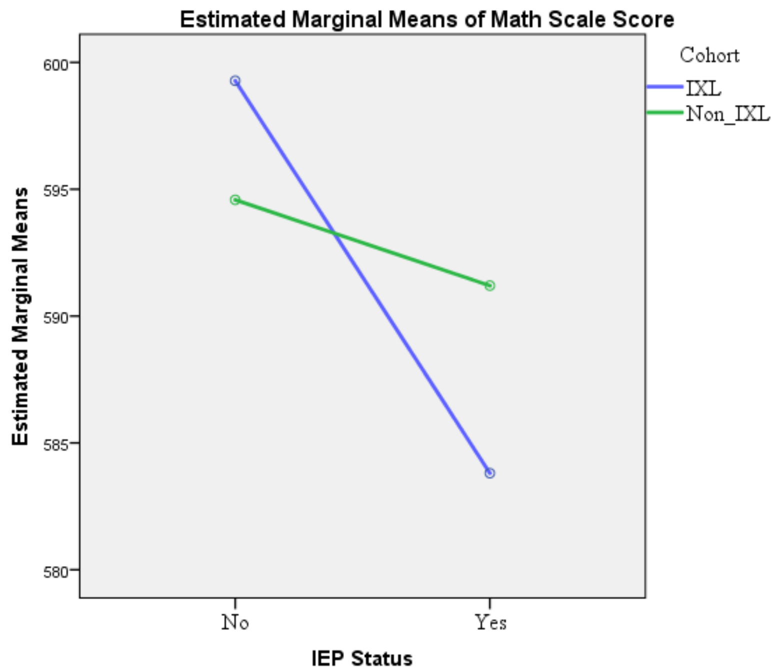
Dependent Variable: Math Scale Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10166.166[a]	3	3388.722	12.880	.000	.077
Intercept	111341670.200	1	111341670.200	423176.086	.000	.999
Cohort	144.461	1	144.461	.549	.459	.001
IEP	7049.080	1	7049.080	26.791	.000	.055
Cohort * IEP	2897.669	1	2897.669	11.013	.001	.023
Error	122082.832	464	263.110			
Total	165814759.000	468				
Corrected Total	132248.998	467				

a. R Squared = .077 (Adjusted R Squared = .071)

Figure 5.

Line Graph demonstrating Mean Scores relative to IEP Status and Cohort Type



Null Hypothesis 5: There is no direct positive correlation between IXL usage, standards mastered and assessment performance.

A Pearson's correlation was used to determine if a relationship exists between the math scale score, the time students spent practicing on IXL, the number of problems attempted, the number of standards mastered. The data are presented in Table 18. There was a small, but not statistically significant, positive correlation between usage time and scale score, $r\ (234) = .13$, $p = .05$. There was a statistically significant, small positive correlation between problems attempted and scale score, $r\ (234) =.18$, $p =.005$. There was a statistically significant, moderate positive correlation between skills mastered and scale score, $r\ (234) =.47$, $p <.001$.

Table 18.
Correlations between Time Spent, Problems Attempted, Skills Mastered and Math Scale Score

		Time Spent (minutes)	Problems Attempted	Skills Mastered	Math Scale Score
Time Spent minutes	Pearson Correlation	1	.879**	.628**	.126
	Sig. (2-tailed)		.000	.000	.054
	N	236	236	236	236
Problems Attempted	Pearson Correlation	.879**	1	.694**	.183**
	Sig. (2-tailed)	.000		.000	.005
	N	236	236	236	236
Skills Mastered	Pearson Correlation	.628**	.694**	1	.472**
	Sig. (2-tailed)	.000	.000		.000
	N	236	236	236	236
Math Scale Score	Pearson Correlation	.126	.183**	.472**	1
	Sig. (2-tailed)	.054	.005	.000	
	N	236	236	236	468

**. Correlation is significant at the 0.01 level (2-tailed).

Supplemental Analysis – Average Utilization of IXL

The results of the current study were surprising in that it was expected, based on the literature review in Chapter 2, that IXL would demonstrate significant differences overall by cohort and by each subgroup. Therefore, in an effort to greater understand possible reasons as to this outcome, additional analysis was conducted. Since there was a relationship shown in this current study between skills mastered and scale score, an average utilization of IXL was calculated by each of the subgroups, as they relate to the research questions, and by grade as it relates implementation of the treatment.

Gender and IXL utilization. Regarding Gender and IXL utilization, a non-statistical comparison of the averages, presented in Table 19, was calculated and showed that female and male students spent approximately the same amount of time, attempted the same number of problems and mastered nearly equivalent number of skills. This may account for the non-statistically significant result with respect to gender as the utilization was approximately equal on average.

Table 19.
Average Utilization of IXL by Gender

Gender	Time Spent (minutes)	Problems Attempted	Skills Mastered
Female	1434	2308	28
Male	1262	2216	25

Ethnicity and IXL utilization. Regarding Ethnicity and IXL utilization, a non-statistical comparison of the averages, presented in Table 20, was calculated and showed that White students spent the most time on IXL, attempted the most problems and mastered the highest number of skills. Asian student spent about the same amount of time on IXL as Black and Hispanic students but attempted approximately 13% more problems and mastered about nearly 1.5 times more skills. This may explain why there was a significant difference found relative to ethnicity and scale score. Further, Black and Hispanic students spent approximately the same amount of time as Asian students, but attempted the fewer number of problems and mastered approximately 50% less skills. This too may account for the statistically significant difference between the ethnicity and scale score. As this present study demonstrated, there was a significant moderate relationship between skills mastered and scale score. This points in the direction that Black and Hispanic students must work towards mastery while using the IXL software.

Table 20.
Average Utilization of IXL by Ethnicity

Ethnicity	Time Spent (minutes)	Problems Attempted	Skills Mastered
Asian	1212	2319	31
Black	1240	2031	21
Hispanic	1274	2066	22
White	1562	2688	35

Disability Status and IXL utilization. Regarding disability status and IXL utilization, a non-statistical comparison of the averages, presented in Table 21, was calculated and showed that students with disabilities spent more time on IXL, attempted about the same number of problems, but mastered about 40% less skills than students without disabilities. This may account for the statistically significant difference between the disability and scale score. As this present study demonstrated, there was a significant moderate relationship between skills mastered and scale score. This points in the direction that students with disabilities must work towards mastery while using the IXL software.

Table 21.
Average Utilization of IXL by Disability Status

Disability Status	Time Spent (minutes)	Problems Attempted	Skills Mastered
Without	1326	2268	29
With	1416	2228	17

Ethnicity, Gender and Disability Status and IXL utilization. Taken together, the average utilization was calculated for ethnicity, gender and disability to help understand specifically which subgroup may require academic intervention, and which groups are not benefitting from the IXL software. These data are presented in Table 22. In general, it was determined that for each subgroup combined, students with a disability status mastered fewer skills. Surprisingly, Hispanic male students with disability status achieved one more skill mastered than Hispanic male students without disability. In particular, excluding Asian students because of low sample size, Black and Hispanic female students with a disability status, mastered 40% less skills. This points in the direction that students with disabilities, especially Black and Hispanic female students, must work towards mastery while using the IXL software.

Table 22.
Average Utilization of IXL by Ethnicity, Gender and Disability Status.

Ethnicity	Gender	Disability	Time Spent (min)	Problems Attempted	Skills Mastered
Asian	Male	Without	1400	2730	32
		With	242	505	1
	Female	Without	1150	2152	36
		With	732	1280	10
Black	Male	Without	1126	2037	22
		With	1055	1897	15
	Female	Without	1387	2092	23
		With	1282	1866	11
Hispanic	Male	Without	1190	2011	21
		With	1628	2319	22
	Female	Without	1182	2038	25
		With	1497	2071	15
White	Male	Without	1342	2541	35
		With	1364	2070	16
	Female	Without	1783	2766	43
		With	1968	3682	26

Grade level and IXL utilization. Lastly, the average utilization for IXL was calculated by grade level. The data is presented in Table 23. The data are surprising: 8th grade spent 75% less time on IXL, 76% less problems attempted, and 58% fewer skills mastered than the highest utilizing grade – the 7th grade. This may be due in part to the former 7th grade students who were considered accomplished were accelerated into 9th grade Algebra 1, and it may also be due to the homework assignment choices of the 8th grade teacher as it appears there were far less assignments.

Table 23.
Average Utilization of IXL by Grade Level

Grade	Time Spent (minutes)	Problems Attempted	Skills Mastered
6th	1386	2392	29
7th	1876	3124	33
8th	475	746	14

Independent samples t-test for 7th grade only. Additionally, since the 7th grade had the highest utilization of the middle school grades, and since this study demonstrated a significant positive moderate relationship with skills mastered and scale score, an independent t-test was conducted to see if there was a significant difference between the means of the scale scores of the IXL and Non-IXL cohorts for only the 7th grade.

Levene's Test of Equality of Variances was conducted, $F(156) = .02$, $p = .88$ and the assumption was satisfied because the p value ($p = .88$) was greater than the confidence interval ($\alpha = .05$), and therefore the variances are assumed to be equal.

The result of the independent samples t-test were: $t(156) = 3.3$, $p < .001$, 95% CI [3.89, 15.83]. In this analysis, the p value (.001) is less than the alpha value (.05). This data suggests that the means, presented in Table 24, of only 7th grade IXL-Math and Non-IXL Cohorts are statistically significantly different. The mean for the 7th grade IXL cohort

(M = 597.57, SD = 19.15) was significantly different than that of the 7th grade Non-IXL cohort (M = 587.71, SD = 18.35.) – nearly 10 points higher!

These findings combined with the utilization levels demonstrate that it is necessary to work towards skill mastery while using IXL Math as the online software can be more effective than Non-IXL traditional paper-based assignments if used to its fullest capacity.

Table 24.

Group Statistics: Comparison of Mean Scale Scores by Cohort for 7th Grade Only

	Cohort	N	Mean	Std. Deviation	Std. Error Mean
Math Scale Score	IXL	90	597.57	19.146	2.018
	Non_IXL	68	587.71	18.347	2.225

Summary of Results

The first purpose of this study was to determine if IXL Math had a positive effective in significantly increasing student achievement on NYS Math exam in a NYC Middle School. With respect to the first hypothesis, an independent samples t-test was conducted, and the results indicated that there was no significant difference in the means of the scale scores between the IXL cohort and the non-IXL cohort. The null hypothesis was accepted, and the findings do not support the idea that using IXL-Math is more effective than Non-IXL traditional assignments. While the means increased, and overall student scores improved, the result was not significantly different.

The second purpose was to examine if IXL Math had a positive effective in significantly increasing student achievement on NYS Math exam for subgroups of students regarding their gender, ethnicity and learning disability status. For gender, a two-way analysis of variance was conducted, and the results indicated that while the mean scale scores for both male and female students increased using IXL, there was no significant difference in the means of the scale scores between male and female students. Regarding ethnicity, a two-way analysis of variance was conducted comparing the effects of ethnicity and cohort type on math achievement, specifically the sales scores. The results indicated that while there was no significant difference in cohort type, IXL vs. Non-IXL, there was a significant difference among the ethnicities of students. To determine where this difference existed among the ethnicity types, further post-hoc analysis was conducted. There was no significant difference in the interaction of cohort and ethnicity as they relate to math achievement. However, further examination of the results indicated that black and Hispanic students performed below white and Asian students using IXL. Most concerning, is black students achieved lower mean of scale score using the IXL software as compared to the traditional paper-based assignments.

Regarding IEP status, a two-way analysis of variance was conducted to determine if a significant difference in the means of the scale scores between students with and without disabilities and whether they experienced the IXL treatment. There was no significant difference in the main effects of IEP or Cohort type was obtained, yet a significant difference in the interaction effect of IEP and Cohort resulted. The results indicated that students with disabilities performed below those students without disabilities with Non-IXL, and to an even lesser degree using IXL.

The third purpose was to find if a relationship exists between IXL usage (time spent in minutes), the number of problems attempted and number of standards mastered with the scale score achievement on the NYS math assessment. A Pearson's correlation test was conducted, and it was first determined that a small positive correlation existed between usage time – the time students spent practicing on IXL and their scale scores. However, this was not statistically significant. The results also provided a small positive correlation that was statistically significant with respect to the number of problems attempted and scale score. Most interesting, is there was a moderate positive correlation which was statistically significant between the number of skills mastered and scale score while using the IXL software.

CHAPTER 5

Discussion

The goal of this research study was to evaluate the effectiveness of IXL Math online software in raising middle school student achievement on the New York State Math exam, with special focus on effects by student gender, ethnicity and disability status - students who are most at-risk, and whose attributes comprise the lowest third percentile of achievers. A quasi-experimental research design was conducted by comparing two distinct cohorts of students – one using traditional paper assignments, the control group, and the other completing IXL online assignments, the treatment group, and determinations were made if there were significant differences in the Math scale scores between the two groups. The following research questions were examined in this study:

1. Does IXL Math have a significantly positive impact on student achievement?
2. Are there significant differences in achievement by gender, ethnicity or disability using IXL Math?
3. Is there a correlation between IXL usage, questions completed, and standards mastered and assessment.

Interpretation of Findings

Research Question 1. With respect to the first research question, it was found that there was no significant difference in the means of the math scale scores between the IXL-Math and Non-IXL cohorts. However, IXL demonstrated measureable gains in math achievement as evident by the mean scale scores being greater than the Non-IXL mean scale scores by 2.41 points. Additionally, the standard deviation was less for IXL than for Non-IXL by 1.24 points. This indicated that the scale scores of the IXL cohort were more clustered together around the mean and less spread-out than the scale scores of the Non-IXL cohort, representing less differences in the result and more consistent outcomes of the scale scores using IXL

This fact does not indicate that the use of the IXL online software is more effective than traditional paper-based assignments, nor does it suggest that lower mean scale scores with Non-IXL that traditional based assignments are less effective. The analysis suggests that there is an inconsequential difference between using the two methods.

When one considers the context of the educational goal of improving students' academic achievement as measured on the NYS Math Exam, practical consideration should be given to using IXL-Math. IXL generates efficiencies because it is easy to implement. It allows for differentiation by assigning higher or lower grade levels. Teachers can spend less time finding appropriate levels of work, creating worksheets and making copies. Also, depending on the year-to-year conversion algorithm from scale score to performance levels and proficiency ratings, a several point difference in a student's scale score could mean moving up a level from approaching to meeting proficiency. Educators understand that small increases can lead to large academic gains, and the use of IXL was in a positive direction.

Research Question 2 - Gender. Regarding the subgroups within gender and achievement in math between IXL and Non-IXL cohorts, both male and female students achieved higher mean scale scores using IXL-Math in relation to their counterparts completing Non-IXL assignments, yet the results were not significantly different.

However, IXL-Math is promising from the standpoint of raising student achievement because of the gains achieved in the scale scores for both males and female students. More specifically, the mean scale score of male students in the IXL cohort was greater than the mean scale score of male students in the Non-IXL cohort by three points, and the upper and lower boundaries of the scale scores, plus and minus one standard deviation, were greater than Non-IXL by 3.1 and 2.69 respectively.

Female students experienced a different result. The mean scale score of female students in the IXL cohort was greater than the mean scale score of female students in the Non-IXL cohort by 1.83 points. Yet the female scale score upper boundary was 0.97 points less, and lower boundary was 4.63 points greater than Non-IXL. Female students in the lower end of the spectrum of scores increased their scale scores the most. This is a positive outcome for IXL.

Research Question 2 - Ethnicity. With respect to the variable of ethnicity (Black, White, Hispanic and Asian students) a two-way ANOVA was conducted. The main effect of cohort type, and the interaction effect between ethnicity and cohort type indicated no significant difference in using IXL-Math. Yet the main effect of ethnicity yielded a significant difference in the mean scale scores using IXL-Math.

There was a significant difference in the mean scale scores of Black and Hispanic students as compared to White and Asian students using IXL software. This means that IXL-Math demonstrated a consequential role in raising achievement for some, but not for all students. White and Asian students achieved a much higher mean scale score than Black and Hispanic students. The difference in mean scale score for students using IXL-

Math was: White students – 5.64 points greater, Asian students – 8.4 points greater, Hispanic students – 2.6 points greater, and Black students – 3.54 points lower!

Additionally, for Asian students, the upper boundary was 6.4 and the lower boundary was 10.4 points greater, indicating that IXL pushed students to excel at all levels. For White students, the upper boundary was 2.3 points higher and the lower boundary was 9.25 points greater, indicating that IXL helped those students the most who were struggling. For Hispanic students. the upper boundary was 2.5 points higher and the lower boundary was 2.7 points greater, suggesting that IXL helped both struggling and accomplished students at about an equivalent degree.

Lastly, for Black students, the upper boundary was 6.35 points less and the lower boundary was 0.73 points less, indicating that IXL not only did not help both struggling and accomplished students, but also has a greater deleterious effect on the accomplished students – those on the higher side of the scale score spectrum decreased more. For these students, clearly the IXL software did not work, and the conversion calculation from scale score to performance level and proficiency rating could drop substantially – perhaps decreasing an entire level or more moving these students down from approaching proficiency to below proficiency.

Research Question 2 - Disability Status. Relative to IEP status (students with and without disabilities), a two-way ANOVA was conducted. Although the main effect of cohort type provided no significant difference, the main effect of IEP status on math achievement, and the interaction effect between IEP status and Cohort type yielded a significant difference

Students without IEP's exhibited 4.7 points greater means scale scores in the IXL-Math cohort as compared to the Non-IXL cohort. Similarly, the upper boundary (mean plus 1 standard deviation) was 2.89 points higher and the lower boundary (mean minus 1 standard deviation) was 6.51 points higher, indicating improvement at both ends of the spectrum with greater improvement at the lower side. This is a positive direction with the use of IXL.

The result is very different for students with IEP's. Students with disabilities displayed a 7.39 lower mean scale score in the IXL cohort as compared to the Non-IXL cohort, with the upper boundary calculated at 11.63 points lower and the lower boundary resulting in 3.15 points lower. Clearly IXL-Math did not serve these students well.

Research Question 3. Lastly, a Pearson's correlation was conducted to see if a correlation existed between time spent, number of problems attempted and number of skills mastered using IXL-Math and the mean scale score. With respect to time spent, there was a small positive correlation between it and the scale score, but this was determined to be not significant. Regarding the number of problems attempted, there was a small positive correlation between it and the scale score, and this was determined to be significant. This is not surprising as evidenced by the increases in the mean scale scores of the IXL cohort relative to the Non-IXL cohort. The gains made by cohort type, gender and three of four ethnicities demonstrate that as students attempt more problems the degree of difficulty increases and this will contribute to higher scale scores. Lastly, relative to number of skills mastered, there was a moderate positive correlation, and this was determined to be significant. This is a consequential result and indicative of the importance of students exerting effort to work through the various levels that IXL takes students through – even those that are very challenging with greater consequence of an incorrect answer – translating into higher scale scores on the NYS Math Exam.

The data indicated that it is quite important to encourage students to not only attempt many problems at progressively more difficult degrees, but also to work towards mastery. Since there was a small positive correlation for time spent and number of problems attempted, these two factors may have contributed to the number of skills mastered as having a greater correlation at the moderate level. Although no causation was implied, simply that a moderate positive correlation exists, the data informed this study that the greater number of skills a student masters, the greater the mean scale score will be.

However, the correlation may be mitigated by two confounding factors not part of the scope of this study, a) accomplished students' skill level, and b) struggling students' skill level. It must be recognized that more accomplished students may take less time and complete fewer questions than struggling students to achieve mastery. On the other hand, struggling students may spend a lot of time on IXL and answer many questions, yet may never achieve mastery. This means that the students' mathematical acumen may play a role in addition to IXL's, and that IXL alone is not able to move students upwards towards mastery. For students who were able to improve their skills through practice, make connections between various skills, preserve through the "Challenge Zone" to achieve mastery, IXL demonstrated it played a significant role in improving student performance on the NYS Math Exam.

Relationship between Results and Prior Research

Findings not aligned with prior research. There have been numerous studies that show technology in the classroom can enhance student results and deliver positive outcomes in achievement. Zengin (2016) examined the effect of a flipped classroom using Khan Academy combined with GeoGebra and Maxima on student mathematical achievement, and the results were significant. It was concluded that these technologies were effective methods of enhancing students' understanding of mathematical concepts. Contrary to these prior results, this study found no statistical difference in the use of IXL vis-à-vis Non-IXL practice methods. IXL was used as the sole technology product in the current study, and perhaps if it was combined with another software product or used in a flipped classroom method of instruction in completing homework with the teacher, that may have resulted in significant differences with respect to the IXL mean scale scores.

Another study by Gatti (2013) reported significant gains in math achievement with a diverse population of at-risk students using technology combined with a Response to Intervention program. Similarly, a case study (Stobaugh, Chanlder & White, 2015) integrated IXL Math into its Response to Intervention (RTI) program reported "widespread improvement at the school level and in individual student gains." Due to this prior research it was believed if IXL can increase student achievement of at-risk students, it could help the subgroups in the current study that comprise student who are most at risk. Unfortunately, the current study is not consistent with Gatti (2013) or Stobaugh, Chanlder and White (2015) because it resulted in the lowest achieving students as performing even lower on the state exam with the use of IXL. The reason may be because unlike with an RtI program, where students are working with a teacher in a classroom, the students in this study completed work independently for homework without teacher involvement. This suggests that students with disabilities require more teacher attention.

A meta-analyses of research on technology-based instruction in the classroom conducted by Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011) found a significantly significant, small to moderate positive average effect size with computer-assisted instruction. Another study (Bennet, 2010) comparing the impact math software and traditional textbook instruction to learning mathematics indicated that there was a statistically significant difference between the two groups – one using the software and the other receiving traditional instruction. The prior studies concluded that math software programs increased student performance. While IXL has many features that should enhance student achievement, this study's findings were not aligned to Tamin, et al (2011) and Bennet (2010) The reason may be that while IXL has many positive features, it is not considered a "computer-assisted instruction" program, and does not render content to students. Rather, IXL's primary purpose is providing unlimited practice and not delivering content or providing remediation.

An extensive evaluative study of various online educational products used in mathematics instruction by Brasiel, Jeong, Ames, Lawanto, Yan and Martin (2016) reported that technology-based instruction had a positive effect on student proficiency levels as measured by the state mathematics assessment. Given this prior research about the positive outcomes of educational technology, it was believed that IXL would demonstrate a significant effect on student math achievement. Unfortunately, the findings in this research study was inconsistent with this previous research. IXL did not demonstrate significant difference in achievement as compared to traditional paper-based assignments. Although the results are not significant, IXL still holds promise of improving outcomes as evidenced by the higher mean scale score.

Findings aligned with prior research. There have been numerous studies demonstrating that IXL has not proven to deliver significantly different results with respect to math achievement. This study's findings are consistent with Longecker (2013) research that found no significant difference in increasing math achievement scores using IXL-Math. Longecker reported declines in scores, which also aligns to the current study's finding relative to Black students and students with disabilities and IXL-Math. This is interesting because both studies were of urban areas, and perhaps the geographical environment plays a role in achievement. Another study, Arms (2019) analyzed the impact of IXL on learning outcomes and concluded that there is no statistically significant interaction between the treatment, gender or socio-economic status and their respective proficiency growth. This result is aligned with this study's findings relative to cohort type and gender. Another similar finding of the Arms study is the proficiency level was slightly higher for students using IXL than those completing paper assignments. The current study found evidence of greater scale scores with IXL utilization. The author suggested that it is what teachers are doing in the classroom that makes the difference in learner's skill and ability.

Copeland and Beach (2014) conducted a study comparing IXL to another software product and found that while both products had a positive impact on learning, IXL was not as effective as the other educational technology product. It went on to report that there was no significant difference between gender or by different abilities.

While the finding regarding gender aligns with the current study, the finding regarding students with disability does not. The current study found significant difference between students with disability and those without, which indicates that educators must provide greater support and encourage mastery completion for students with special needs while they work with IXL.

Hollands and Pan (2018) evaluated IXL and found no significant increase in gains with IXL as compared to another educational technology product. This is aligned to the results of the current study relative to gender and disability that there was no significant difference. Results that also aligned to the current study was the mean scale scores of IXL were greater the other product in the prior study. This was the same as the present study where the scale scores of IXL were greater than the Non-IXL cohort. Copeland and Beach (2014) concluded that the teacher combined with the technology plays a major role in improving math achievement meet performance goals. Also, Hollands and Pan (2018) found no significant gains in using IXL and suggested that IXL, while helpful, is not equipped to deal with complex problems and multi-step problem-solving. Taken together these ideas suggests that the teacher is the most important factor in improving student achievement by helping students to make connections between concepts in order to solve complex problems, and be responsible for supplanting the technology with rich and rigorous question types much like those experienced on the NYS Math Exam.

Additionally, Schuetz, Biancarosa and Goode (2018) found when comparing the results of IXL math intervention with a paper and pen treatment, teachers reported IXL as having greater levels of engagement and independence among young learners. Teachers were able to differentiate and to scaffold more effectively by assigning topics up and down grade levels. It allowed accomplished students to work at their own pace and with more challenging problems, while teachers assisted and supported those who struggled with the content. While this prior research hold promise, the present study demonstrated that students may not have been willing to work towards mastery. If they were then the correlation between skills mastered and scale score may have been stronger. Students seem to stop working once they reach the Challenge Zone as the threat of losing points dropping a level and starting again is too great.

Gender and relationship to prior research. Several studies prior to the current study found that female students performed at higher levels than male students in both the utilization of computer programs and the completion of traditional paper-based assignments (Spradlin & Ackerman, 2010). Brown (2018) compared the effectiveness of competing homework using IXL with traditional paper and pen completion of homework on gender and mathematical achievement. The results were not significant, yet female students achieved greater mean sores on the assessment than male students. These findings were an interesting result because it was also true for the current study. In both the IXL and Non-IXL cohorts, female students achieved higher mean scale scores. However, consistent with Hatfield (2019) there was not a statistical significant difference associated with gender and mathematical achievement. Also, Clark (2014) compared traditional instruction and computer-based instruction supplemental to the traditional instruction and found no significant difference in math achievement scores between the genders on the state's standardized test. The results of the current study are in the same directions as these prior studies, and indicate that nothing different should be done between male and female students. However, Feng, Roschelle, Mason & Bhanot (2016) reported that a statistical difference existed between the genders using different software products other than IXL. Therefore, it is reasonable to conclude that if a consequential difference existed between male and female students, then perhaps a different approach would be employed for each of the genders while using IXL. However, with respect to using IXL, Brown (2018) found no statistical difference between genders using the software. The current study's finding is aligned with Brown's, which suggests that a different approach to male and female students may not be necessary with respect to using IXL. Yet, it is noted in the present study that the mean scale scores of male students were below that of female students. This result may be due to the larger number of male students than female students. This suggests that perhaps different forms of progress monitoring, differentiation, and motivation may be required for male students when using the IXL system in order to effect higher positive outcomes. This idea is affiliated with Pellegrini, Lake, Inns and Slavin (2018) study which found evidence that supported the idea that IXL-Math is as not effective as other pedagogical approaches and software. The authors accentuated the need for educators to look for programs that offer personalization, engagement, and motivation. These elements, they contend, had the most impact on mathematics instruction, and perhaps this is what male students need to succeed.

Ethnicity and relationship to prior research. Since ethnicity is a contributing attribute to the lowest third of achievers, with Black and Hispanic students forming a large proportion of at-risk students, the desire to improve their mathematical achievement is a matter of equity and moral duty. Prior research has revealed that technology can help close the achievement gap by addressing the specific learning needs of individual students of various ethnicities (Huang, Craig, Xie, Graesser, Okwumabua, Cheney & Hu, 2013), and that Hispanic students can benefit from educational technology as well (Park, Lawson and Williams, 2012)   Additionally, prior research has demonstrated that greater, and utilization levels of online educational products by students of color was positively associated with improved mathematical achievement (Ahn, Beck, Rice and Foster, 2016). As such, it was hoped that IXL would be able to address the needs of low achieving Black and Hispanic students. While Hispanic students increased their mean scale scores using IXL, the result was not significant; the increase was only marginal. What was most surprising is Black students experienced a decline when using IXL, and this finding was statistically significant.   While this result is aligned with the prior research of Longecker (2013) and Clark (2014) which found a significant difference in achievement scores between Black and Hispanic students and White students, it is not the outcome that was hoped for and expected using IXL. Altogether, this indicates greater utilization of educational technology and direct involvement of the teacher personally, and addressing the needs of these students with greater differentiation is what is required.

Disability status and relationship to prior research. Another large contributing characteristic of the lowest third of achievers are students with disabilities. Fortunately, Xin, Tzur, Hord, Liu, Park & Si (2017) found in their research that students with learning disabilities can improve their mathematical problem-solving skills through the use of computer- assisted instruction. McLeod (2011) concluded that "teachers believed that instructional technology is improving achievement with students with learning disabilities in mathematics." It was believed based on prior research that use of technology like IXL would motivate students who are at-risk, and be used to raise the achievement of all students regardless of background or ability. Surprisingly, the current study's findings were inconsistent with the above prior studies. Students with disabilities performed lower using IXL at a statistically significant difference than completing the Non-IXL paper-based homework. This suggests that the teacher played a major role in addressing the needs of these students as it relates to their learning and success. This idea is supported by a study conducted by Stultz (2013) which concluded that the differences in traditional instruction versus computer instruction directs our attention to a greater need for human interaction for special need students.

Connection to theoretical & conceptual framework.

Zone of proximal development. IXL is based on students achieving mastery of various mathematics skills, relative to their grade level. The zone of proximal development (ZPD) is demonstrated when the level of questions a student can perform on his or her own without assistance from a teacher. IXL is designed to increase a level, and become increasingly more difficult as a student completes questions correctly. It is also designed to decrease a level, and offer easier questions if the student answers incorrectly. In both cases the system is automatically adjusting to match a student's skill level. However, a struggling student who answers hundreds of questions, or spends hours working on a single topic, and earns a low score would require a more knowledgeable other, a teacher, to help guide them towards greater success, as the theory suggests. This seems to be the case with students with disabilities who spent comparable time on IXL and attempted approximately the same number of questions, but mastered far fewer skills. Similarly, if an accomplished student who answers several questions, spends a few minutes on the system, and achieves 100% score, the he or she is not operating at the highest range within the zone of proximal development. This seems to be the case with Asian students who spent about the same amount of time as other students, but mastered many more skills. The results of the current study point in the direction that is necessary for the teacher to intervene and to provide work that is suitable for both struggling and accomplished students - each operating at their respective ranges within the zone of proximal development in order to be academically successful.

Competency-based learning. Competency-based learning allows students to move through an individualized learning plan at a self-regulated pace with a focus on achieving mastery (TeachThought, 2018). Competency-based learning is evident in IXL with students working at their own pace and at their own degree of difficulty of questions. The system automatically adjusts to the student's skill level depending on whether or not they answer correctly. The goal for students is to achieve mastery with a SmartScore of 100%, having worked though the challenge zone. This current study found a moderate, statistically significant, positive correlation between skills mastered and mean scale score.

Personal learning. Personalized learning is a student-centered approach to learning based on mastery (Dreambox Learning, 2018). The aim of a student's education should be for them to achieve mastery, and to do so by completing increasingly more difficult material. For this to occur, schools must be willing to adapt to meet individual learner needs (Herold, 2016). IXL is designed to offer personalized learning by offering a continuous diagnostic that makes individual recommendations based on a students' mastery level. The system automatically assigns topics for students to complete - either to strengthen their performance with skill on which they did not achieve mastery, or to challenge them with questions of a greater degree of difficulty. While this feature of IXL holds much promise, it may be possible that it was underutilized in the current study. There is no way to measure whether or not students in the IXL cohort completed the diagnostic in utilization reports. It seems from the data, students completed only the work they were assigned by teachers and did not engage with diagnostic feature. If teachers required the diagnostic and subsequent recommendations to be completed, then perhaps the mean scale scores of the IXL cohort could have been even greater than reported, and maybe statistically significant.

Differentiated instruction. One of the strengths of IXL is its ability for teachers to easily differentiate, but the system cannot do it alone. The system's value is enhanced when it offers differentiated, individualized and personalized instruction (ISTE, 2018). Effective teachers address student differences thoughtfully and proactively (Tomlinson & Imbue, 2010), and must think about the numerous levels of student accomplishment and modify instruction to meet their needs (Poncy, Fontanelle & Skinner, 2013. The data of the current study supports the idea that the teacher in the classroom plays a large role in addressing the needs of the student, as evidenced by the non-significance of the results. If teachers utilized the IXL system more effectively with greater differentiation according to need and ability, or provided a blend of multiple skills together within one question, or offered multi-step problems then perhaps the results would have resulted in better outcomes for students.

Data-driven decision-making. To thoughtfully and intentionally use student data to measure growth, and to act on that data accordingly **is** an effective way to improve student achievement. Data-Driven Decision-Making uses diagnostic data to inform instructional decisions (Mathematica, 2014). IXL makes it possible for teachers to identify struggling and accomplished students and to allows for re-grouping of students for remediation or enrichment activities. The current study evaluated the effectiveness of IXL as it related to the completion of homework assignments completed independently by students without the aid of a teacher. However, if a teacher involved in the IXL treatment had utilized the data to determine which students were having difficulties from those who were not, and investigated which topics they needed guidance or further challenge, with re-grouping and re-teaching both struggling and accomplished students, the results of the IXL cohort may have been better. Knowing who is struggling and who is succeeding, based on the data, and the ability to offer differentiation of assignments is the real power of the IXL online software program.

Connection to technology framework for technology-based instruction.

Theory of memory. Shiffrin and Atkinson (1969) indicate that practice improves performance. They suggested that informational organization with respect to coding and storage of information within one's memory impacts retention and retrieval of that information. The authors point towards practice as necessary to improve the storage and recall of information, and that skills are improved with increased procedural memory. IXL offers hope that students would improve their skills and remember how to solve certain problems with increased practice as they work towards mastery. However, the current study's findings were not statistically significantly when comparing the means of the scale scores of the two cohorts. The Theory of Memory suggests that students were not practicing enough, or they were practicing skills that were unrelated to the skills tested on the NYS Math Exam. The results indicated that the mean scale scores for IXL were greater than Non-IXL, and there was a positive, moderate correlation between the scale score and the number of skills mastered. The data support the concept that additional practice can produce positive outcomes, but according to Hollands and Pan (2018), the right type, and quantity, of practice is necessary.

Observational learning. As described by Fryling, Johnston and Hayes (2011), Bandura's research suggested learning was comprised of two parts: acquired skills comprised of attention and retention, and performance-based tasks including reproduction and motivation. It was posited that modeling behavior and providing positive and negative consequences can influence behavior, but drew a distinction between learning and performing a task. The authors also indicated that activities that were practiced immediately after being learned resulted in better outcomes. While IXL can activate a student's memory by providing a model solution, the success of this process is dependent upon the learner to read, interpret and make meaning of the solution provided – there is no opportunity to ask questions or provide feedback. It is not the same as paying attention to a teacher modeling a solution on Smart Board and then checking for understanding prior to independent practice. Additionally, the IXL system does not readily address misconceptions as well as a teacher would in a classroom setting. It does however, in keeping with Bandura's theory, by providing student recognition of positive outcomes with written displays and declarations such as, "Excellent, Well Done, Wonderful and Good Job!" as well as awarding colorful badges for achieving various levels of academic accomplishment. Although IXL features align with this theory, the system did not achieve a level of statistical significance when comparing the two cohorts' effectiveness. The good news is higher levels of mean scores were attained using the

IXL online system, and with respect to the 7th grade, the difference in means were significant. As student complete more problems, and achieve mastery, they have additional opportunities to be rewarded, which reinforces the behavior. The Theory of Observational Learning suggests that greater utilization of IXL's motivational devices of charts and certificates by classroom teachers would have a positive impact.

Automaticity. Logan (1988) advanced the idea that learning process are connected to repetitive tasks and practice. The theorist suggested that skill acquisition was enabled and enhanced through the building of memory with repetitive practice. As a skill was increasingly practiced, the successful performance of a task was more reliant on memory and less on problem solving. This result was completing the task became automatic. It was believed that IXL would improve performance because of its provision of unlimited practice questions – far more than any worksheet a teacher could provide. While, this was true for the 7th grade only analysis as the difference was significant and by nearly 10 points, the IXL cohort means were also higher than the mean of the Non-IXL cohort, but they were not significantly different. It is known from the data that there was no correlation between time spent answering questions and scale score. It is also known that the number of skills mastered and scale score was statistically significant, and there was a moderate positive correlation with skill mastered and scale score. What this means is that while the results of this present study point in the direction of automaticity theory, it also suggests from the prior work of Hollands and Pan (2018) that the type pf practice is important as well. IXL is focused on individual skills. IXL is not furnished to deliver complex, multi-step questions. Once again, the role of the teacher would come into play in providing question types similar to those that students would be asked to answer on the NYS Math Exam. Since the Non-IXL cohort completed paper-based homework, perhaps the teachers provided questions more suited to success on the exam.

Connection to limitations of educational technology use in mathematics instruction. Some of the most effective instructional strategies do not require the use of technology, and prior research shows that these methods can provide greater academic outcomes. Marzano, Pickering & Pollock (2001) provided nine such instructional strategies, from notetaking and summarizing to homework and practice. Additionally, Ritchhart, Church, & Morrison (2011) and Kitchens (2012) provided several other non-technological instructional as effective ways to enhance student mathematical achievement. Further, Slavin, Lake and Goff (2009) provided a best-evidence synthesis of 100 studies and reported that Cooperative Learning had a higher effect size for middle school students. Combining the results of the current study which found no significant difference in the mean scale scores between the IXL and the Non-IXL cohorts, the prior work of researchers, suggests what a teacher does in the classroom matters, and technology cannot do the job alone. Teachers keeping students engaged and motivated, using appropriate instructional strategies to address their individual learning needs, and supplementing technology with traditional and effective pedagogy are the driving force behind student achievement. Perhaps if IXL was used in the classroom, in conjunction with these strategies, greater mean scale scores could have been attained.

Connection to technology-based homework support. There was clear evidence from several prior studies that a homework-achievement relationship exists. Cooper, Robinson and Patall (2006) conducted an extensive meta-analysis and reported positive effective size ($d = .39$ to $.97$) on achievement outcomes for students completing homework. Although a causal relationship was not implied, students completing homework versus students not completing homework performed significantly higher on unit tests. The study suggested that the level of achievement would be different for each student, as the level of achievement is dependent upon how much homework is assigned by the teacher, or how much is completed by the student. It was clear from the average utilization reports by grade, that there was a large amount of homework assignments made by the 7th grade teacher, and substantially less homework assignments made by the 8th grade teacher. The latter most likely had a negative impact the current study's result. Further, the number of problems attempted and skills mastered varied by the subgroups using IXL. So while not all teachers assigned the same amount of homework, not all students completed the homework, or would strive to achieve mastery with SmartScore of 100%. This suggests that the level of achievement would be different for each student, as the level of achievement may be dependent upon how much homework is assigned by the teacher and completed by the student. Perhaps if more students using IXL achieved mastery, the results may have been significant.

Roschelle, Feng, Murphy, and Mason (2016) concluded that that online mathematics homework coupled with providing immediate and personalized feedback, has a positive impact on mathematics achievement. Using the reporting capabilities of IXL to personalize learning by providing immediate feedback would have been beneficial. Examining homework feedback and its impact on student mathematical achievement, with a concentration of the IXL homework features, Mahmood (2017), reported that IXL had among the lowest increase in scale scores on the New York State mathematics exam, and effort-based feedback was the highest. While IXL provides immediate feedback as students progress through the levels, it is the same type of statement, like “wonderful” or “terrific.” Perhaps if IXL were offer reinforcement by praising students with statements that recognize effort, such as, “Great effort”, “Don’t give up” or “Keep working hard”, it would have encouraged more students to persevere to complete more problems, and master more skills. Further, Mahmood (2017) research indicates that the most effective feedback is from human beings. It is the teacher who is in the best position to offer feedback through empathy, support and encouragement. Perhaps the results would have demonstrated a significant difference, if effort-based feedback and if IXL was completed in the classroom in order to receive human input.

Connection to professional development and use of educational technology. Professional development is critical to using educational technology, and the ability of teachers to use IXL in an impactful way is dependent upon practical and easy to implement systemized training (Knight, 2012). As students enhance their success, teachers become more accepting of adopting new approaches of instruction (Dam, et al., 2018). One obstacle is finding time to collaborate with colleagues to gather and analyze data to make informed decisions about student learning needs. (Gleason, et al, 2019). Lastly professional development must be on-gong, long-lasting focused on educational technology, coupled with evidence-based instructional strategies offers large potential to improve mathematical achievement of all types of students. (Bicer & Capraro, 2017)

The current study offered a formal one-to-one professional development session with each of the teachers involved with the treatment. The session consisted of establishing class rosters, demonstrating the method of making assignments and obtaining scores, progress monitoring with the use of completion charts, printing of certificates, and using the diagnostic tool. Not included in the training was a demonstration of how to use the "Analytics" tools including the "Trouble Spots", "Questions Log", "Progress" and "Live" tabs to gauge time on task, problems attempted and skills mastered. These analytical tools, if there was time to teach the teachers, may have revealed a student spending a lot of time on a skill and not rising in difficulty level requiring remediation, or a student who achieves mastery within a few minutes and requires enrichment with more challenging work. It is possible, had this training been provided, the current study would have shown statistically significant different results, indicating improved academic achievement.

Limitations

Threats to statistical conclusion. The threats to statistical conclusion are the following: low statistical power in that the sample size is small; there were only 468 students in the sample. A larger sample would provide greater statistical power. There was also low reliability of treatment implementation in that multiple teachers decided how to best use the IXL system in the making of homework assignments, and as a result, the utilization rate was different for each grade. Greater adherence to treatment would provide greater statistical power.

Threats to internal validity. The threats to internal validity are low reliability of treatment implementation. There were multiple teachers involved in using the IXL program, and teachers decided how and to what extent they wanted to use the program. Additionally, there was variation in the motivational techniques (charts and certificates) used to encourage students to complete their homework using IXL-Math. Lastly, student who were considered accomplished in 7th grade, were accelerated into Algebra 1, a 9th

grade curriculum, and did not participate in 8th grade IXL activities, while students in the Non-IXL cohort completed 8th grade curriculum.

Threats to external validity. The threat to external validity is conducting a generalization across treatments. Since the treatment sample was from the Early College Initiative in a middle school in New York City, and the control sample was from a neighboring school within the same district, the inferences would not be applicable to elementary or high school students within the same geographic area, nor would they be applicable to students of different geographic areas that are not Title 1, urban and of diverse demographics.

Recommendations for Future Research

There are eleven recommendations for future research regarding the effectiveness of IXL. They are enumerated as follows.

1. The first is to utilize a larger sample, either from larger schools or to create a sample from multiple schools to provide greater generalizability.

2. The second is to conduct a longitudinal study. The current study consisted of one academic year, and it is suggested to conduct a study three to five years to measure student growth over time. Since students and teachers may become more adept at using the IXL software, and small increases lead to large gains over time, the benefits of IXL may become more apparent with a long-term study.

3. The third is to conduct a study with more grades each participating in it from elementary, middle school and high school levels. Prior studies, including this study, included grades separately. A broader view as to IXL's impact on achievement on

multiple grade levels from one school district may serve to more clearly demonstrate where IXL is least and most effective.

4. The fourth is to conduct a qualitative study measuring student perception and motivation. Students are the reason the system was built, and it would behoove educators to know and understand how receptive they are to using it. Understanding students' pleasure and discomfort with IXL, may allow educators to address motivational issues. The greater the comfort and motivation, the greater the utilization may be and the furtherance of academic achievement will be realized.

5. The fifth recommendation is to compare IXL with another educational online system. Rather than comparing IXL to another non-technological approaches, a head-to-head evaluation of the two systems and their relative impact on student academic achievement would be most beneficial. The two systems could be run parallel with or sequential to one another utilizing the same sample, or a comparison made between two different samples, a control and target group.

6. The sixth is to focus studies more on students and less on teacher perception. While it is easier and more convenient to work with adults because the requirement for parental permission is not necessary, it is of vital concern to know and understand what students are thinking and feeling – their total experience – in using the IXL system.

7. The seventh is to cross analyze the overlap between ethnicity and disability status and number of skills mastered. A key finding of this study was that black students and students with disabilities decreased in their scale scores by using IXL. This study also pointed out a moderate positive correlation between number of skills mastered and scale score. Therefore, it would be most beneficial to determine if black students and

students with disabilities were not striving for mastery, or underutilizing the system, and to address their academic needs.

8. The eighth is to make a prediction the measurement of IXL utilization that would result in a significant difference between the means. IXL Learning makes a recommendation that 15 to 20 minutes of daily practice has a positive impact on achievement. This study found a small positive correlation with no significant difference in time spent and scale score. An independent evaluation which can support and validate that utilization claim is necessary if districts are to purchase a subscription.

9. The ninth recommendation is to conduct a study to determine that if students use IXL for multiple content areas in addition to IXL-Math and determine whether or not an expanded subscription and utilization would have a positive impact on student achievement. IXL Leaning research claims that for schools using IXL for three years outperformed Non-IXL schools by 13 points on the math Performance Index. It would be beneficial for schools and school districts to validate this claim to make a financial investment decision in supporting academic achievement.

10. The tenth recommendation is to conduct a study of the professional development provided to teachers, the fidelity to treatment, and the outcome of improved academic achievement. One threat to internal validity of this study was a certain degree of variation between teachers in using the IXL system as it ranged from small to large number of questions completed. Greater uniformity in assigning topics, utilizing awards and certificates, monitoring student progress, and grading should strengthen the validity and generalizability of the study’s findings.

11. The final recommendation is to review established models of memory. Given the ease of acquiring information through the internet, more people are reliant on their personal devices. No longer does certain information need to remembered as it can be researched instantly. The availability of reference tools through the internet may be changing memory and how it processes information. This could be impacting students' ability to recall, learn and problem solve, and perhaps the current models of memory, with the interaction of the internet, need to be updated to reflect current circumstances.

Recommendations for Future Practice

It was believed that IXL would improve the scale scores of all students regardless of background or ability in a significant way. The data suggests that IXL can improve the scale scores on the New York State math exam, however, the results were not statistically significant. However, in subsequent analysis, the results were statistically significant for the 7th grade only, suggesting that working towards mastery can have a profound impact on achievement. However, while providing students an opportunity to improve their skills, IXL may not adequately address the skills necessary for achievement on the New York State Math exam. Therefore, it is critical for educators to supplement student practice with more difficult and complex, multi-step questions to solve. Further it is evident from the analysis that there is a moderate positive relationship between the number of skills mastered and mean scale score. It is critical therefore to encourage and support students to work towards and achieve mastery. Motivational devices such as posting completion charts and printing certificates from the IXL system can aid in this regard.

It is most concerning for Black and Hispanic students, those with IEP's and those who do not work towards mastery of the various state-aligned standards that they have not improved in increasing the scale score. Teachers must know how to use IXL data reports and analytics in order to use the data to measure growth – to see who is struggling and with what skills. Teachers must address the academic needs of those students with re-teaching, or assigning the same topic a grade level lower to strengthen students' skill.

It is critical as educators that the technology not be used as a replacement for the teacher, but rather as a supplement to rigorous differentiated instruction. While IXL's strength is providing unlimited skill practice, it cannot address student mathematical misconceptions, frustrations and feelings – especially when they become discouraged because the work is too hard. Moreover, it is the educator's responsibility to ensure that all students, particularly those who are at-risk, are utilizing the system to its fullest, ensuring that every individual is achieving mastery by working through the most difficult problems. Teachers using IXL must be vigilant about making informed differentiated decisions about instruction to push all students to reach their fullest potential. IXL has many data reporting features offering the potential of increasing student achievement if used to its fullest capacity.

Bringing the above recommendations together will require the involvement and dedication of school or district administrators. As educational leaders, they must articulate a vision for using educational technology, define the problem to be solved, select the proper software to align with addressing the needs of students, and set clear expectations for system utilization and data-mining to make instructional decisions. Leaders need to know the system's abilities and limitations, and provide comprehensive and sustained professional development so that teachers can harness the power of educational technology in promoting greater student achievement. As teachers experience their students' success using online systems, both parties will begin to utilize the systems more - building more achievement. As the age-old adage states, "Success breeds success."

Lastly, it is suggested that software engineers and program developers offer multi-step, complex problems for students. For IXL, this could be offering a student who completes several individual skills that relate to a complex problem, such as solving multi-step equations, a capstone exercise of solving a challenging question that encapsulates several mathematical skills. This would offer a set of challenging questions for accomplished high performing students with which to work. Also, prior research has shown that elaborative feedback is most impactful in terms of raising student achievement. Therefore, it is suggested that IXL modify its generic positive statements such as "Terrific" to a more effort-based statements, such as "Great Effort! Keep Working Hard! Never Give Up!" This type of praise motivates students to strive towards excellence especially as they power-through the Challenge Zone and work towards mastery.

Conclusion

Reflecting on the findings, the researcher concludes that IXL can have a positive impact on student achievement. In order to do so, the system must be utilized to its fullest capacity, and several inter-related instructional activities must occur. This involves several things: a) motivating students to achieve mastery by offering praise for their effort, and encouraging them to continue working hard by providing completion charts and certificates that recognizes and rewards achievement, and not just completion, b) using data and reports that exist in IXL to differentiate instruction by identifying students who are struggling and require teacher guidance – with special attention given to black and Hispanic students, and students with disabilities – those who are most vulnerable and need greater support, c) determining the skills that students are not mastering by using IXL's extant data and provide re-teaching and remediation, d) providing supplemental material comprised of multi-step, complex questions to all students to they become familiar with the types of questions presented on state assessments – especially for those accomplished students who require enrichment and challenge. Doing these things may help garner the power of educational technology and fulfill IXL's potential of improving student achievement for all students.

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