The Impact of Technology Factors Beyond School on Eighth-Grade Math Achievement

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Abstract

This study examined the relationship between technology factors students use beyond school and their standardized math assessment scores. Student frequency of seeking math help online, playing digital games involving math, and programming computers outside of school were studied. An analysis of data taken from the National Assessment of Educational Progress (NAEP) dataset was done to compare student responses from survey data to mathematics achievement scores of 8th-grade students. This secondary data analysis was completed using multiple *t*-tests to compare means and determine significance. Results found in this study showed that beyond school, frequent use (daily or almost) of websites for math homework help, playing digital games involving, and programming computers had negative effects on scores. Once/twice a year or month scored better than never for website use and digital games, while never programming scored higher than all other frequencies. Students may benefit from instructional guidance as to which websites are most beneficial for homework help with math. An effort to help students recognize math use in digital games may increase their awareness and intentional use outside of school. Early classroom instruction on computer programming may help provide a better understanding of its relationship with mathematics.

Keywords: NAEP, mathematics achievement, data mining, technology use, mathematics education, computer programming, digital games

1. Introduction

1.1 Introduce the Problem

The concerns surrounding achievement in mathematics for students in the United States has been at the forefront of education and research for decades. Recent scores on international tests from the Programme for International Student Assessment (PISA) test does not indicate encouraging results (*PISA 2018 Results*, 2018). Programs such as STEM (science, technology, engineering, and math) that focus on bolstering interest and engagement in math in order to increase achievement scores have fallen short of the intended impact. The scores on the Trends in International Mathematics and Science Study (TIMMS) for the United States in eighth-grade math show only a slight increase in the average from 1995 to 2015, but still places the U.S. far below other countries (*Trends in International Mathematics and Science Study (TIMSS)—Overview*, n.d.).

1.2 Needs for Study

The fear of not competing academically with other countries has driven the U.S. to conduct more research on educational practices in the math classroom. This research has focused primarily on school-related factors and family related factors. Previous research has been found to report inconsistent findings as to the influence of these factors with regard to achievement (Abdelfattah & Lam, 2018; Carmichael & McDonald, 2014). Some studies have looked to increase math achievement through examining student motivation, both intrinsic and extrinsic, only to determine that most students at the middle school level are heavily influenced by extrinsic factors such as grades or rewards (Herges et al., 2017). In addition to extrinsic motivation, many students claim that using technology for homework purposes enhances their learning experience (Abdelfattah & Lam, 2018).

1.3 Discrepancies in Relevant Scholarship

In order to increase mathematics achievement and compete globally, a better understanding is needed as to the motivating factors and best practices in the classroom, as well as factors of student behavior beyond school. Research has not heavily focused on factors beyond school other than family support and homework in terms of quantity and quality (Abdelfattah & Lam, 2018). This study is focused on investigating these factors that have been widely overlooked in previous studies. Exploring student behavior outside the classroom compared to achievement levels is needed to fill this gap. Math-focused activities that are technology-based, such as digital games involving math, may lead to an increased understanding of math concepts (Fokides, 2018). Further examination of technology-based activities outside of school can offer insight into potential factors that may increase math achievement.

1.4 Purposes of the Present Study and the Framework for the Study Design

The purpose of this study is to explore the relationship between the 2019 NAEP eighth-grade composite math scores and student factors beyond school in technology-based math activities. Findings from this study will assist educators and parents in providing a look at any possible relationship between math-related activities outside the classroom and the level of mathematics achievement inside the classroom.

This study will focus on answering the following research questions in order to examine this relationship:

1. What impact does the use of websites for math help outside of school have on 8th grade NAEP math scores?
2. What impact does playing digital games that involve math outside of school have on 8th grade NAEP math scores?
3. What impact does programming computers outside of school have on 8th grade NAEP math scores?

Our theoretical framework for this research adopts a scientific inquiry-based approach. The framework was described in great details in The Impact of Conversations on Fourth Grade Reading Performance - What NAEP Data Explorer Tells? (Bond & Zhang, 2017). In summary, the research methods combined the inquiry process with scientific knowledge, reasoning, and critical thinking. We started with an extensive exploration of the dataset, and that led to the designing of the research questions. The research questions further guided us to mine the data with great in-depth.

2. Literature Review

Achievement in mathematics has been an underlying educational concern for decades. The race to be on par with or ahead of other countries when it comes to student performance in mathematics has been the focus of many federal and state programs over the years, most implemented with little success. As recently as 2018, the United States fell below the average on the Programme for International Student Assessment (PISA) test for mathematics taken by fifteen-year-old students in 79 countries (*PISA 2018 Results*, 2018). In order to better understand this lack of achievement, it is necessary to take a closer look at factors that are possibly influencing students who do succeed, particularly those factors that take place outside of the school environment. Four themes are discussed in this literature review to align with the focus of this study. They are (1) technology and math, (2) seeking math help online, (3) digital games involving math, and (4) math and computer programming.

2.1 Technology and Math

The development of new technology depends heavily on mathematics as the relationship between these two fields is long-standing. The use of technology is just as prominent in the study of mathematics. For decades, calculators have been incorporated in classrooms for computation and graphing to aid in the understanding of mathematical concepts. Klecker and Klecker (2014) found that students using graphing calculators most of the time during math class had a higher average scale score than students who did not use graphing calculators on the 2013 NAEP 12th grade Mathematics assessment. Students have also been found to experience enhanced learning and achievement when using technology by accessing mobile applications for math instruction (Etcuban & Pantinople, 2018). As these studies show the promises of utilizing technology during classroom instruction, investigations have been lacking in determining the effects on math achievement of student use of technology outside the classroom.

2.2 Seeking Math Help Online

From tutoring websites to video instruction, online help for math concepts is readily available. This access to instruction outside the classroom has the potential to impact student understanding while working on assignments beyond school. Most students do not have access to instructors or tutors at home to aid in grasping concepts without turning to technology. A study by Roschelle et al. (2016) showed that students using an online platform to complete homework that provided feedback and hints had greater achievement in math than students using traditional worksheets for homework. This type of embedded assessment encourages students to think critically about their own learning while completing assigned work (Chappell et al., 2015). The affordances offered in online math help give the students instant clarification and extra guidance while they're engaged with concepts.

Websites are available to further explain and tutor via text and video. Tutorial sites like Khan Academy, MathisFun.com, or YouTube instructional videos, offer free (although limited) access to a variety of topics to aid students in their studies. Using technology to access math help at Khan academy in the classroom has been found to have a positive effect on student achievement in math (Leon & Koosed, 2018). This effect needs to be examined when the process of seeking this online help occurs outside the classroom. These sites allow students to seek guidance without relying on teachers or parents to prompt them (D'addato & Miller, 2016).

Another common method of accessing math help online is accomplished through crowdsourcing in discussion forums. These forums are commonly found on social media sites and open forums such as Reddit. Students post questions on concepts in hopes that others will offer aid in problem-solving. This type of online help comes with challenges and limitations. Crowdsourcing for information may not be immediate as users are in different time zones and may not be reliable for accuracy as the expertise of the user providing assistance is not always verifiable (Kim & Thacker, 2020). Even with these obstacles, students are still posting to open forums in search of guidance on concepts.

2.3 Digital Games Involving Math

Playing digital games has become a favorite activity for many teens. Although not all these games are educational, many do involve the use of mathematics to problem solve and progress successfully through the game sequence. Using digital games involving math in the classroom has been shown to increase learning outcomes (Fokides, 2018). This form of math application may increase interest and comprehension of concepts. As students engage in these games involving math, their degree of autonomy increases, allowing them greater control of their learning (Fokides, 2018). Applying the math learned in school to digital games played outside of school can spark motivation to further explore concepts. Students have often indicated that gameplay is their preferred mode for learning (Fokides, 2018).

Although many digital games that use math are based on simple drill and practice of basic concepts, which could arguably lead to improved math skills, most do not engage users in higher-order thinking and math problem solving (Byun & Joung, 2018). Increasing basic skills will certainly aid in increasing achievement, but an exploration of more robust games involving critical thinking with math application is warranted. These types of game settings are often worked collaboratively through teamwork. Students working together on digital math games have also shown to have increased learning and math achievement (Fokides, 2018).

The popularity of digital games has fueled the tech industry and spurred educational-based games to compete in this industry. A study from Zhang (2014) using web analytics found that the popularity of math game websites grew rapidly between 2008 and 2014. With this evolving interest shown in digital games involving math, a closer examination of these games and their potential to impact achievement is advocated.

2.4 Math and Computer Programming

Computer programming has made its way into middle school and high school curriculums with course offerings for over a decade. The inclusion of mathematical concepts in the fields of computer science and programming is well known and has generally followed that certain math courses are completed prior to or in conjunction with courses in these fields. In a study by Benton et al. (2018), the relationship between math and computer programming was investigated to determine the value of using programming to better understand the math concept of place value. Many students were found to have successfully navigated the computer programming and engaged with the mathematical content from a new perspective (Benton et al., 2018). This study showed the promise of connecting math and programming as a real-world application to both motivate and increase student achievement in mathematics.

Programming has shown to be beneficial with other math concepts as well. Spatial awareness, a crucial skill for geometry, trigonometry, and calculus, has been found to increase with computer programming practice (Messer et al., 2018). This relationship between math and programming has been determined to be strong. Students with a good mathematics base tend to be more successful in programming courses (Owolabi et al., 2014). Encouraging this connection in classrooms and outside of school may strengthen overall math achievement. Students learning computer programming alongside mathematics tend to show an increase in their self-efficacy in mathematics (Psycharis & Kallia, 2017).

While many previous studies centered on examining the topics of students seeking online math help, playing digital games involving math, or programming computers, there has yet to be a study that examines the impact of these practices outside of school on national math test scores.

3. Method

The National Center for Educational Statistics (NCES) administers the NAEP test for mathematics every two years. The NAEP Data Explorer (NDE) was used to collect data from the 2019 test in order to examine the assessment of 8^{th}-grade math achievement and study the possible gender gap in the impact of social-based and technology-based activities beyond school. A secondary analysis of the data used a quantitative descriptive research design to discover any possible patterns or trends in the data (Larose & Larose, 2014). This section further describes the data source, sample, and analysis used in this study.

3.1 Participants and Sampling

Participants are chosen through a multistage probability sample design that enables NAEP to use a representative sample of the entire population while giving each participant an equal chance of being selected (National Center for Educational Statistics (NCES), 2019). The NAEP mathematics assessments are given every two years with the most recent conducted between January and March 2019. Across the nation, these tests were completed on tablet computers by 147,400 eighth-grade students (NCES, 2020). This study examines the math scores of eighth-grade students in the nation's public schools.

3.2 Sample and Data Collection

The participants selected by NAEP, based on a probability sampling, create a sample that is representative of the nation. The 2019 math assessment was administered via digital devices with a score range of 0-500, and students were allowed 60 minutes to complete the test. Students were also given a questionnaire to complete regarding their activities inside the school and beyond school pertaining to mathematics (NCES, 2020). Test data for the eighth-grade math assessment consists of scores in five categories, (1) number properties and operations, (2) measurement, (3) geometry, (4) data analysis and probability, and (5) algebra (NCES, 2011). A composite score is also available and is the score used in this study. The NCES (2013, para. 4) states that "the composite scale is a weighted combination of these subscales."

3.3 School Selection and Year

The U.S. Department of Education's public-school system database is used to identify the public schools to select from. Nonpublic schools are also selected to be considered for sampling. These schools are then categorized by location type (urban, rural, etc.) and then again according to the racial/ethnic composition of the school. These categories are sorted by achievement level on state assessments to ensure a representative sample is chosen. NCES selects schools from each category with probability relative to the population of schools. To guarantee sufficient representation, schools with high minority populations, smaller schools, and private schools are all sampled. The final list of selected schools is confirmed for eligibility to participate by the Department of Education in each state. NCES administers the NAEP Mathematics test to 4^{th}-, 8^{th}-, and 12^{th}-grade students every two years, with the most recent being assessed in 2019 (NCES, 2020).

3.4 Data Analysis

The NAEP Data Explorer allows users to analyze the data by creating descriptive tables and calculating *t*-tests to determine possible significance in the difference between the means of groups. These tables and tests were used to analyze the data from the 2019 8th grade math composite scores for national public schools by gender for student factors beyond school based on social and technology-focused activities. Cohen's *d* effect size was calculated using the University of Colorado's "Effect Size Calculator" (Becker, 2000). Cohen's *d* is used to compare two means in order to determine the difference between them in terms of standard deviations (Cohen, 1992). This allows a closer examination of the strength and importance of any significance found in the data.

3.5 NAEP Data Explorer

The NAEP Data Explorer provides users the tools needed to explore the NAEP assessment results. Data can be examined by year of assessment or subject of assessment and divided into a variety of groups based on student, teacher, or school factors. As mentioned in the previous section, Data Analysis, statistical analysis functions are available in the NDE tool for investigating possible relationships in the data. For this study, the following coded questions were selected for further exploration through NDE:

- How often do you participate in each of the following activities outside of school? Go to websites for help with your math homework. Options: Never; Once/twice a year; Once/twice a month; Once/twice a week; Ever day or almost [M831304]
- How often do students play digital games outside of school that involve math? Options: Never; Once/twice a year; Once/twice a month; Once/twice a week; Ever day or almost [M834401]

- How often do you practice in each of the following activities outside of school? Program computers. Options: Never; Once/twice a year; Once/twice a month; Once/twice a week; Ever day or almost [M831302]

4. Results

This section will report the results of examining the student factors beyond school involving technology use and the NAEP 2019 eighth-grade math scores for students in national-public schools. These results include the means and standard deviations for each variable pertaining to the research questions, as well as independent t-test results to determine significance. Cohen's *d* effect size was calculated to further examine any significance found. Each Cohen's *d* effect size was calculated using the University of Colorado's Effect Size Calculator (Becker, 2000). The results pertaining to each research question (RQ) are presented here individually.

4.1 RQ #1: How Often Do You Go to Websites for Help With Your Math Homework Outside of School?

Table 1 shows the 2019 math scale score and standard deviation for eighth-grade national-public school students based on their reported frequency of using websites for math help outside of school.

Table 1. Average scale scores and standard deviations for 8th-grade math, by frequency of using websites for math help outside of school [M831304]

Year	Jurisdiction	Frequency of using websites for math help	Average scale score	Standard deviation
2019	National-Public	Never	280	39
		Once/twice a year	288	41
		Once/twice a month	287	39
		Once/twice a week	280	38
		Every day or almost	266	40

NOTE: Some apparent differences between estimates may not be statistically significant.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment.

Students who stated that they never go to websites for math help had an average scale score of 280 (SD=39). Students reporting that they go to websites for math help once or twice a year had an average scale score of 288 (SD=41). The average scale score for those indicating that they go to websites for math help once or twice a month was 287 (SD=39). The remaining students reported going to a website for math help once or twice a week (M=280, SD=38), or they reported a frequency of every day or almost (M=266, SD=40).

The differences in means and independent *t*-test results for the frequency of going to websites for math help outside of school are shown in Table 2.

Table 2. Difference in scale scores between variables for frequency of using websites for math help outside of school [M831304]

	Never (280)	Once/twice a year (288)	Once/twice a month (287)	Once/twice a week (280)	Every day or almost (266)
Never (280)					
Once/twice a year (288)	> Diff = 9 P-value= 0.0000 Family size = 10				
Once/twice a month (287)	> Diff =7 P-value= 0.0000 Family size = 10	< Diff = -2 P-value= 0.0144 Family size = 10			
Once/twice a week (280)	x Diff = 0 P-value= 0.5204 Family size = 10	< Diff = -9 P-value= 0.0000 Family size = 10	< Diff = -7 P-value= 0.0000 Family size = 10		
Every day or almost (266)	< Diff = -14 P-value= 0.0000 Family size = 10	< Diff = -23 P-value= 0.0000 Family size = 10	< Diff = -21 P-value= 0.0000 Family size = 10	< Diff = -14 P-value= 0.0000 Family size = 10	

LEGEND:

< Significantly lower.

> Significantly higher.

x No significant difference.

NOTE: Within jurisdiction comparisons on any given year are dependent with an alpha level of 0.05.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment

Students who reported using websites for math help outside of school once/twice a year or once/twice a month had an average scale score that was significantly ($p<.001$) higher than those who never used websites for math help. Those who stated they used websites for math help once or twice a month had an average scale score significantly ($p<.001$) lower than those who used websites for math once/twice a year. Those who stated they used websites for math help once or twice a week had an average scale score significantly ($p<.001$) lower than those who used websites for math once/twice a year or once/twice a month. Students who indicated they go to websites for math help every day or almost had average scale scores significantly ($p<.001$) lower than all other frequencies.

Cohen's *d* effect size was calculated on the independent *t*-tests that indicated significance in order to determine its strength. Effect sizes measure the magnitude of the factor involved and can be categorized as .2 being small, .5 as medium, and .8 as large. Positive and negative Cohen's *d* values indicate improvement or deterioration in a predicted direction (Becker, 2000).

Table 3 shows Cohen's *d* effect size of the significant mean score differences when using websites for math help outside of school.

Table 3. Effect sizes of significant mean score differences when using websites for math help outside of school [M831304]

		Cohen's *d*
Once/twice a year	Never	0.20
Once/twice a month	Never	0.18
Once/twice a month	Once/twice a year	-0.02
Once/twice a week	Once/twice a year	-0.20
Once/twice a week	Once/twice a month	-0.18
Every day or almost	Never	-0.35
Every day or almost	Once/twice a year	-0.54
Every day or almost	Once/twice a month	-0.53
Every day or almost	Once/twice a week	-0.36

Between students reporting that they use websites for math help every day or almost and all other reported frequencies, the effect size fell in the medium range, with the highest effect size (-0.54) between students reporting using websites for math help every day or almost and those reporting as using websites for math help once/twice a year. The effect size between students reporting using websites for math help once/twice a month and those using websites once/twice a year was the lowest at -0.02. All other pairs of frequencies with a significant difference had a small effect size.

4.2 RQ #2 - How Often Do You Play Digital Games Outside of School That Involve Math?

Table 4 shows the 2019 math scale score and standard deviation for eighth-grade national-public school students based on their reported frequency of playing digital games outside of school that involve math.

Table 4. Average scale scores and standard deviations for 8^{th}-grade math, by frequency of playing digital games that involve math outside of school [M834401]

Year	Jurisdiction	Outside school play digital games that involve math	Average scale score	Standard deviation
2019	National-Public	Never	283	40
		Once/twice a year	291	41
		Once/twice a month	286	40
		Once/twice a week	277	39
		Every day or almost	276	38

NOTE: Some apparent differences between estimates may not be statistically significant.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment.

Students who stated that they never played digital games outside of school that involve math had an average scale score of 283 (SD=40). Students reporting that they played digital games outside of school that involve math once or twice a year had an average scale score of 291 (SD=41). The average scale score for those indicating that they played digital games outside of school that involve math once or twice a month was 286 (SD=40). The remaining students reported that they played digital games outside of school that involve math once or twice a week (M=277, SD=39) or, they reported a frequency of every day or almost (M=276, SD=38).

The differences in means and independent *t*-test results for the frequency of playing digital games outside of school that involve math are shown in Table 5.

Table 5. Average scale scores and standard deviations for 8th-grade math, by frequency of playing digital games that involve math outside of school [M834401]

	Never (283)	Once/twice a year (291)	Once/twice a month (286)	Once/twice a week (277)	Every day or almost (276)
Never (283)					
Once/twice a year (291)	> Diff = 8 P-value = 0.0000 Family size = 10				
Once/twice a month (286)	> Diff = 3 P-value = 0.0002 Family size = 10	< Diff = -5 P-value = 0.0000 Family size = 10			
Once/twice a week (277)	< Diff = -6 P-value = 0.000 Family size = 10	< Diff = -13 P-value = 0.0000 Family size = 10	< Diff = -9 P-value = 0.0000 Family size = 10		
Every day or almost (276)	< Diff = -8 P-value = 0.0000 Family size = 10	< Diff = -15 P-value = 0.0000 Family size = 10	< Diff = -10 P-value = 0.0000 Family size = 10	< Diff = -2 P-value = 0.0029 Family size = 10	

LEGEND:

< Significantly lower.

> Significantly higher.

x No significant difference.

NOTE: Within jurisdiction comparisons on any given year are dependent with an alpha level of 0.05.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment

Students who reported playing digital games outside of school that involve math once/twice a year or once/twice a month had an average scale score that was significantly ($p<.001$) higher than those who reported never playing digital games outside of school that involve math. Those who stated they played digital games outside of school that involve math once/twice a month had an average scale score significantly ($p<.001$) lower than those who played digital games outside of school that involve math once/twice a year. Those who stated they played digital games outside of school that involve math once/twice a week had an average scale score significantly ($p<.001$) lower than those who reported never playing digital games outside of school that involve math, those who reported playing digital games outside of school that involve math once/twice a year, and those reporting once/twice a month. Students who indicated they played digital games outside of school that involve math every day or almost had average scale scores significantly ($p<.001$) lower than all other frequencies.

Table 6 shows Cohen's *d* effect size of the significant mean score differences when playing digital games outside of school that involve math.

Table 6. Effect sizes of Significant Mean Score Differences when playing digital games that involve math outside of school [M834401]

		Cohen's *d*
Once/twice a year	Never	0.20
Once/twice a month	Never	0.08
Once/twice a month	Once/twice a year	-0.12
Once/twice a week	Never	-0.15
Once/twice a week	Once/twice a year	-0.35
Once/twice a week	Once/twice a month	-0.23
Every day or almost	Never	-0.18
Every day or almost	Once/twice a year	-0.38
Every day or almost	Once/twice a month	-0.26
Every day or almost	Once/twice a week	-0.03

Students indicating that they played digital games outside of school that involve math once/twice a year and those who reported they never played digital games outside of school that involve math produced a Cohen's *d* effect size of 0.20. The effect sizes between students reporting that they played digital games outside of school that involve math once/twice a month and those reporting that they never played digital games outside of school that involve math or played digital games outside of school that involve math once/twice a year were 0.18 and -0.12, respectively. The effect sizes between students reporting that they played digital games outside of school that involve math once/twice a week and those reporting that they never played digital games outside of school that involve math, played digital games outside of school that involve math once/twice a year, or played digital games outside of school that involve math once/twice a month were -0.15, -0.35, and -0.23, respectively. The Cohen's *d* effect sizes between those indicating that they played digital games outside of school that involve math every day or almost, and those who reported playing digital games outside of school that involve math never, once/twice a year, once/twice a month, or once/twice a week were -0.18, -0.38, -0.26, and -0.03, respectively.

4.3 RQ #3 - How Often Do You Program Computers Outside of School?

Table 7 shows the 2019 math scale score and standard deviation for eighth-grade national-public school students based on their reported frequency of programming computers outside of school.

Table 7. Average scale scores and standard deviations for 8th-grade math, by frequency of programming computers outside of school [M831302]

Year	Jurisdiction	Frequency of programming computers	Average scale score	Standard deviation
2019	National-Public	Never	285	38
		Once/twice a year	282	42
		Once/twice a month	273	40
		Once/twice a week	272	41
		Every day or almost	265	44

NOTE: Some apparent differences between estimates may not be statistically significant.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment.

Students who stated that they never program computers outside of school had an average scale score of 285 (SD=38). Students reporting that they program computers outside of school once or twice a year had an average scale score of

282 (SD=42). The average scale score for those indicating that they program computers outside of school once or twice a month was 273 (SD=40). The remaining students reported programming computers outside of school once or twice a week (M=272, SD=41), or they reported a frequency of every day or almost (M=265, SD=44). The differences in means and independent *t*-test results for the frequency of programming computers outside of school are shown in Table 8.

Table 8. Difference in scale scores between variables for frequency of programming computers outside of school [M831302]

	Never (285)	Once/twice a year (282)	Once/twice a month (273)	Once/twice a week (272)	Every day or almost (265)
Never (285)					
Once/twice a year (282)	< Diff = -4 P-value = 0.0000 Family size = 10				
Once/twice a month (273)	< Diff =-12 P-value = 0.0000 Family size = 10	< Diff = -8 P-value = 0.0144 Family size = 10			
Once/twice a week (272)	< Diff = -14 P-value = 0.000 Family size = 10	< Diff = -10 P-value = 0.0000 Family size = 10	x Diff = -2 P-value = 0.1053 Family size = 10		
Every day or almost (265)	< Diff = -20 P-value = 0.0000 Family size = 10	< Diff = -17 P-value = 0.0000 Family size = 10	< Diff = -8 P-value = 0.0000 Family size = 10	< Diff = -6 P-value = 0.0000 Family size = 10	

LEGEND:

< Significantly lower.

> Significantly higher.

x No significant difference.

NOTE: Within jurisdiction comparisons on any given year are dependent with an alpha level of 0.05.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Mathematics Assessment

Students who reported programming computers outside of school once/twice a year, once/twice a month, or once/twice a week had an average scale score that was significantly (p<.001) lower than those who never programmed computers outside of school. Those who stated they programmed computers outside of school once/twice a month or once/twice a week had an average scale score significantly (p<.001) lower than those who programmed computers outside of school once/twice a year. Students who indicated they programmed computers outside of school every day or almost had average scale scores significantly (p<.001) lower than all other frequencies.

Table 9 shows Cohen's *d* effect size of the significant mean score differences when programming computers outside of school.

Table 9. Effect sizes of significant mean score differences when programming computers outside of school [M831302]

		Cohen's *d*
Once/twice a year	Never	-0.08
Once/twice a month	Never	-0.31
Once/twice a month	Once/twice a year	-0.22
Once/twice a week	Never	-0.33
Once/twice a week	Once/twice a year	-0.24
Every day or almost	Never	-0.49
Every day or almost	Once/twice a year	-0.40
Every day or almost	Once/twice a month	-0.19
Every day or almost	Once/twice a week	-0.16

The effect size between students reporting that they programmed computers outside of school every day or almost and those who reported never programming computers outside of school was -0.49. Between students who reported they programmed computers outside of school every day or almost and those reporting programming computers outside of school only once/twice a year was -0.40. Students indicating that they program computers outside of school once/twice a month and those who reported they never program computers outside of school produced a Cohen's *d* effect size of -0.31. The effect size between students reporting that they program computers outside of school once/twice a week and those reporting that they never program computers outside of school was -0.33. All other pairs of frequencies with a significant difference had a small effect size.

5. Discussion

This study was undertaken to examine the relationship between average scale scores on the 2019 eighth-grade NAEP mathematics test and technology factors that take place outside of school. Specifically, this study examined the test results against beyond school factors including students' use of websites for help on math homework, playing digital games that involve math, and programming computers. This section discusses the findings that were reported in the results section.

5.1 Websites for Homework Help

Students who reported going to websites for help on math homework once or twice a year had the highest average scale score (M=288; SD=41), followed closely by students who reported this activity as once or twice a month (M=287; SD=39). The lowest average scale score of 266 (SD=40) went to students who used websites for math homework help every day or almost everyday. Students who accessed websites every day or almost had an average scale score significantly lower than all other frequencies. Cohen's *d* calculations between every day or almost and both once or twice a year and once or twice a month produced medium effect sizes, 0.54 and 0.53 respectively.

The low score for those students who seek help online for math homework every day or almost (M=266; SD=40) is in direct disagreement with a study from Roschelle et al. (2016) that found students had greater math achievement when using online sources for homework. As most previous studies looked at the use of online help in aiding students with math work in the classroom, the benefits found do not appear to fully transfer to this practice outside the classroom. Students who indicated they go to websites for homework help in math every day or almost may be students who typically struggle with math and need extra guidance. Low performing students who have access to the internet outside of school have indicated they find help online as beneficial in completing their homework and raising their level of self-confidence in mathematics. (Chappell et al., 2015). As this study did not look at average grades for these students in comparison, it is impossible to determine the school performance level of the students who use websites at this frequency.

For students seeking math help online, the type of website used is not included in the NAEP data. Students seeking help may be using tutorial sites or social media to inquire information on specific concepts. The success of obtaining the information and guidance sought in this endeavor is not measured and may be a contributing factor to the lower scale score for those with higher frequencies. For example, the accuracy of help received in online discussion forums rarely comes from an academic source and often is delayed in response. If this is the case for students using websites every day or almost, their lower average scale score suggests agreement with Kim and Thacker (2020) as to the obstacles of seeking online help.

5.2 Math in Digital Games

Similar to the numbers for using websites for math help, students who played digital games involving math every day or almost had average scale scores significantly lower than all other frequencies. These students had the lowest scale score average of 276 (SD=38), with those playing digital games involving math once/twice a year having the highest average scale score of 291 (SD=41). Although still considered low, the Cohen's *d* size effect between every day or almost and once/twice a year was the greatest (0.38) followed closely by once/twice a week and once/twice a year (0.35).

These numbers look to disagree with a previous study from Fokides (2018) that found digital games involving math increased achievement when used in the classroom. This discrepancy could indicate that home use is not focused and monitored for educational purposes as would be when done in the classroom. Digital games students are engaging in may also be at the drill and practice level and not pushing to critical thinking and application (Byun & Joung, 2018).

Although the popularity of digital games has increased dramatically since 2008 (Zhang, 2014), students may not clearly recognize which games involve math. In answering this question on the NAEP questionnaire, students were left to interpret the meaning of digital games involving math. Previous studies looked at these games as used in the classroom and focused heavily on the involvement of math skills. These games were chosen and used with intention and indicated an increase in achievement levels, albeit to different degrees (Byun & Joung, 2017; Din & Calao, 2001; Fokides, 2018). Students playing digital games involving math outside of the classroom setting are not displaying the same results according to the average scale scores on the 2019 NAEP mathematics assessment.

5.3 Computer Programming at Home

Students who indicated that they never engage in programming computers outside of school (M=285; SD=38) scored significantly higher than all other frequencies. Those who stated they program computers outside of school every day or almost (M=265; SD=44) had average scale scores significantly lower than all other frequencies. When calculating Cohen's d effect size, the significance was found to be greatest between never programming computers outside of school and programming every day or almost at 0.49, basically considered a medium effect size.

These numbers are in disagreement with studies showing the benefits of computer programming to increase math skills and raise student self-efficacy in mathematics (Benton et al., 2018; Messer et al., 2018; Psycharis & Kallia, 2017). This does not necessarily indicate poor math skills, as it has been shown that those with strong math skills tend to excel in programming (Owolabi et al., 2014). It also possible that these students may not possess programming knowledge nor have they engaged in programming courses. However, students who never program outside of school may still be strong in math skills but lacking in access to devices needed for programming. A look at access to home computers in 2015 showed that students in high-income families were far more likely to have this access (KewalRamani et al., 2018). As this study did not separate by socioeconomic status or address classes previously taken, it is not determinable as to the reason why some never program outside of the classroom.

6. Conclusion and Future Research

The continued growth in the field of technology has given many students the opportunity to explore the internet and digital tools in classrooms as well as in their homes. Regardless of socioeconomic status, more than half of all students access digital learning resources at home (KewalRamani et al., 2018). With this level of access, students' behavior at home with respect to technology is an important factor to explore. This study examined the relationship between technology-based factors beyond school and the average scale scores on the 2019 eighth-grade NAEP mathematics assessment. Based on the results found in this study, the following conclusions are presented.

6.1 Websites for Math Help Do Not Guarantee Success

The results of this study suggest that students seeking help with math homework from websites are not scoring higher on math assessments. The likelihood is great that students who turn to websites for math help every day or almost are those who tend to struggle with math as low performing students. This help may be increasing their score compared to what it would be without seeking daily online help, but this is not measurable with the available data.

Although findings in this study indicate that only those seeking math help from websites sporadically, once/twice a year or once/twice a month, achieve higher average scale scores, all students seeking this help may still be increasing their level of self-confidence in mathematics (Chappell et al., 2015). However, the data used does not give us insight into this theory. It follows that the less often students seek online websites for help with math homework, the better their average scale scores will be on the math assessment.

6.2 Digital Games Involving Math: Less Is Better

Evidence provided in the data analyzed by this study suggests that students playing digital games involving math outside of the school setting will score higher on math assessment if only played once/twice a year, once/twice a month, or never played. In other words, playing these games more regularly, once/twice a week or every day, appears to lower the average scale score. The data to address this research question was obtained by asking students to determine their frequency of playing digital games outside of school that involve math. This required students to interpret the math involvement of games they play which then impacted their responses. Some students may have viewed this as only referring to math-based games similar to those used in classrooms, while other students may have considered any math that is done to progress in a digital game, whether it was overtly presented in the game or not.

These results also suggest that playing digital games involving math beyond the school setting does not have the same benefits found in previous studies of digital games involving math are played in the classroom (Byun & Joung, 2017; Din & Calao, 2001; Fokides, 2018). When digital games with math are played at home, students are not receiving the instructional guidance provided by the classroom teacher. This lack of supervision may interfere with students' abilities to recognize and capitalize on the benefits of even the most subtle math used while playing digital games.

6.3 Computer Programming Is Not the Answer

Findings from this study showed students who never engaged in programming computers outside of the school setting had significantly higher average scale scores on the math assessment than any other frequency of programming computers. Reasons for this may include a lack of programming experience for most 8th graders as many schools have not implemented these courses until the high school level as an elective option (Passey, 2017). Without prior knowledge in programming, students will not engage in this as a regular activity outside of school. Although previous studies indicate programming has a positive effect on math achievement, the results in this study show that the more often students program computers at home, the lower their average scale scores are on the NAEP math assessment.

The implications of this study should push educators to investigate the use of technology outside the classroom and its relationship to the use of technology in the classroom. As many previous studies have shown, the implementation of digital games involving math in the classroom has led to increased achievement, but this does not hold for playing digital games involving math outside the classroom. The instruction and guidance educators provide during the playing of these games in the classroom should be examined and adjusted in order to accommodate for the application of math in digital games beyond school. Another finding of this study is that there was not a marked improvement in the average scale scores of students who frequently go online for help implying that they want outside explanations but that they are not finding quality material. Since students may seek help from outside resources, it would be beneficial for teachers to provide proper guidance on which websites could be most useful. Lastly, computer programming outside of school has a negative impact on scale scores. This indicates that students are not connecting this activity with mathematics and could benefit from earlier programming instruction in the classroom setting to better understand this relationship.

6.4 Limitations

A few limitations of this study exist due to the nature of the data. The data obtained from the 2019 NAEP math assessment is considered secondary data and therefore carries any possible validity problems that occurred when the data was collected. This data should not be interpreted as having a cause and effect relationship as the variables were pre-decided, and this could impact correlation analysis. The analysis methods used were provided through NAEP Explorer and were therefore limited in scope.

Another limitation of this study is the heavy reliance on students' individual interpretations of questions in the survey. This is a widely found limitation for survey studies but is especially found in adolescent participants who are at higher risk of finding the wording in standard questionnaires to be ambiguous (Borgers et al., 2000). Student interpretation as to the meaning of digital games involving math can vary widely from math-focused games to a variety of other game genres that utilize math skills covertly to progress through the levels. Finally, the lack of ability to differentiate the data between the types of websites the students accessed for math help on homework is a limitation. It was not possible to determine if students were referring to instructional videos, tutorial sites, social media, etc., as this was open to encompassing all.

6.5 Suggestions for Future Research

This study focused on very limited data from the 2019 NAEP math assessment to examine the relationship between technology-related student behavior beyond school and the average scale scores. The findings pertaining to each research question led to further questions that should be explored. One area to consider is the socioeconomic status of students with regard to their technology access and use at home. Examining this data in conjunction with the data in this study would provide deeper insight into the variation of scores. Further studies of website types would serve to clarify how students are using these for help on math homework and could lead to recommendations for educators and parents on how to guide students in using these resources. Future research on the math involved in various types of digital games may help to inform all with a vested interest as to how students could benefit from these applications. Finally, further research should be done to determine best practices in implementing computer programming in grades earlier than high school.

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