

Computational Thinking Using the First in Math® Online Program

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Abstract: *Students demonstrate many of the component parts of computational thinking skills in a variety of disciplines, such as mathematics, science, and computer science education. Computational thinking is an approach to problem solving--the primary purpose for learning mathematics--that can be implemented with a computer (Barr & Stephenson, 2011). The researcher in this study explored the effects on students' mathematical development when they engage daily with the First in Math (FIM) online program. The results indicated that third, fourth, and fifth graders using the FIM online learning program in an encouraging environment, showed significant improvements in their mathematics achievement. Implications for computational thinking, which underlies the recommendations by National Council of Teachers of Mathematics (NCTM) (2000) and the Common Core State Standards (CCSS) (2010), are that students develop this skill set as a powerful problem-solving tool and can extend it to the essential parts of everyday life.*

INTRODUCTION

The application of computer technology to every aspect of our daily lives has permeated education changing how teaching is done today. Mathematics programs aim to integrate technology in meaningful and useful ways. Seymour Papert (1980), who created the computer language Logo, believed that children learn by doing and then thinking about what they do. For children to learn mathematics, they must be actively involved and have time to reflect on their thinking.

NEED FOR THE STUDY

The understanding and usage of mathematics skills are critical in modern society. In a technological age where computers pervade all aspects of life, knowledge of computers and the related technology is becoming necessary for success, advancement and, perhaps, even survival (Maleski & Elliott, 2005; Gallup Organization, 2013). This study reports the findings of elementary students engaged in the First in Math (FIM) online program.

STATEMENT OF THE PROBLEM

This study focuses on the mental processes, specifically computational thinking students implement as they acquire an understanding of mathematics concepts at their grade level; and, the effect of interacting with First in Math (FIM) online program to learn these concepts.

PURPOSE OF THE STUDY

The study investigates students' thinking processes (computational thinking) and to assess their mathematical achievement as they were learning mathematical thinking skills, which includes fact fluency, procedural fluency, and word-problem solving skills, while engaged with the FIM online program.

IMPORTANCE OF THE STUDY

The Goal Index, an intentional goal-setting feature on the FIM online program, measures students' mathematics efforts in four key areas of computational thinking: 1) persistence in mathematics thinking; 2) fluency in all four operations (addition, subtraction, multiplication, and division); 3) procedural fluency, and 4) word-problem-solving skills. These four key areas are the component parts of computational thinking.

The Pennsylvania State Standardized Assessment (PSSA) scores provide students, parents, teachers, and the school-community important feedback on student learning. Often these scores are the springboard for improvement plans for students who lag academically. Also, the PSSAs help ensure curriculum alignment, address scope and sequence and provide an important measure of teacher and school accountability (Hellrung, 2017).

REVIEW OF THE LITERATURE

Computational thinking, a type of analytical thinking, resembles mathematical thinking, engineering thinking, and scientific thinking in general ways (Wing, 2006). Computational thinking involves problem decomposition, data representation, and modeling for students. Decomposition require students using the cognitive process to describe the total group and then the subgroups of a number. Data representation prompts students to visualize mathematics problems in multiple ways, such as pictures, graphs, symbols, charts and manipulatives as a means of communicating mathematics. Modeling problems often provide the necessary background for developmental strategies and these problems use real world-situations (Standard for Mathematical Practice, CCSS, 2010, p. 72).

Computer scientists, cognitive researchers, and educators continue to debate and discuss the applications of computational thinking. So far, no single widely accepted definition of

computational thinking has emerged which can create a lack of a clear path to develop these important skills for pre-K-12 educators (Barr, Harrison, & Conery, 2011).

Mathematical thinking. An examination of international and national assessments of student achievement shows that the need to reform the way mathematics is taught begins with teaching students to think mathematically by solving nonroutine problems, which conveys that mathematics is a process, something that one “does” (Brahier, 2016).

Engineering thinking. Engineers have a toolkit of mental skills which includes creative problem-solving, visualizing, systems thinking, adapting, and improving. Often engineers break down a problem and then reconstruct it by putting it back together in new way. Good engineers are often described as having reasoning skills, curiosity, and communication and problem-solving skills. “Encouraging children, right from primary school age, to explore through playful experimentation whilst keeping it central to innovation and creativity is enough to help spark these thought processes.” (Lusty, 2017)

Scientific thinking. For this paper, the definition of scientific thinking is knowledge seeking, which encompasses any instance of purposeful thinking that has the objective of enhancing the seeker's knowledge (Kuhn, 2011). Scientific thinking helps young children make sense of their world. Often these skills include observing, asking questions, making predictions, testing ideas, gathering data, and communicating their thoughts. These process skills are found in effective instruction and all content areas including mathematics.

Language of Mathematics. Many students view the language of mathematics as a “foreign” language. Both require making connections to new vocabulary and using that vocabulary in context. Activities that engage students in communicating ideas about mathematics provide students with the opportunity to use mathematical language and make sense of what they are learning. Words, symbols, and graphs are powerful methods of communicating mathematical ideas and relationships. These tools allow students to express mathematical ideas to other people. Moving from one representation to another enhances mathematical concepts. The National Council of Teachers of Mathematics’ (NCTM) *Standards* (2000) recommends that all students create and use representations to organize, record, and communicate mathematical ideas and consolidate their mathematical thinking through communication. In addition, NCTM’s *Curriculum Focal Points* (2007) promotes a focused curriculum from both the concept and content perspectives in which students continually engage in and construct mathematical knowledge.

Environment. Teachers who are genuinely invested and enthusiastic about the FIM program and their students’ learning, influence the participation of their students. Students notice when they have a teacher that is “into it.” One of the most, if not the most, important roles of a

teacher is that of a coach with appropriate amount of gentle encouragement and support. This mix creates and sustains motivation. Some educational scholars refer to motivation as a foundation of effective classrooms. Malloy, Marinek, and Gambrell (2010) noted, “Motivation is the likelihood of choosing one activity over another, as well as the persistence and effort exerted when participating in the chosen activity.” (p. 1) Teachers who encourage students to become active participants and create a community of learners contribute to motivating high levels of student achievement.

Summary. Most students have enthusiastic views toward mobile technology and are more engaged in those activities, which enhances their learning (Fabian, Topping, & Barron, 2018). Even though students have favorable sentiments toward technology and learning, the teacher is the one who chooses how to teach and if technology is a part of the instruction. Many mathematics teachers believe that teaching with technology is an important component of instruction (Kaleli-Yilmaz, 2015). Chen (2011) found that mathematics teachers thought technology use in the classroom was necessary in order to equip students with technological skills for future careers.

When curriculum reflects an understanding of what matters, educators learn to value the way students think by giving them the opportunity to share their learning strategies (Mills, O’Keefe, & Whitin, 1996). Technology effectively integrated in a mathematics classroom has a positive effect on student achievement, but the amount of positive effect varies by which educational technology is put into practice (Cheung & Slavin, 2013). Mathematics teachers today can prepare students to be thinkers and creative problem solvers ready for the workforce by focusing lessons on computational thinking which underlies the recommendations of NCTM (2000) and the CCSS (2010). All careers require a foundation in mathematics, and some are more mathematics intensive.

METHODOLOGY

Participants. Six classrooms participated in the study, which included two classrooms each of third, fourth, and fifth grades at Marvine Elementary School in the Bethlehem Area School District (BASD) located in northeast Pennsylvania. All the students in these grades engaged in the FIM online program.

Setting. Eric Fontanez is the principal of Marvine Elementary in the Bethlehem Area School District (BASD), which is in a low socio-economic community (defined by the number of free and reduced lunches) in northeastern Pennsylvania. The student population consists of 92% students of color, 96% are on free or reduced lunches, and 30-40% are English learners. In 2020, Marvine Elementary received an award from the Pennsylvania Department of Education as a 2019-2020 Distinguished School. Only 94 out of 3,287 public schools in Pennsylvania have earned this

distinction. To qualify for the award schools must be in the top 5% for achievement or be in the top 5% for growth for 2018-2019.

Materials. The First in Math (FIM) online program, a unique mathematics teaching tool for students K-8 created by Robert Sun in 2002, delivers substantive and comprehensive mathematics content, from addition to complex algebra, in a game format. More than 20 million students world-wide have been enrolled in the First in Math online program. This unique teaching tool engages student through an online program that contains more than 240 digital mathematics games and modules including: Very Important Facts (VIFs), Just the Facts (JTFs), GYMs (short cycles and fast paced games), Skill Sets, Know & Show word-problem modules, Computational Thinking (CT) World containing games requiring coding to build computational thinking skills, Player of the Day badges, traveling trophy, and Wall of Fame kits.

Procedures. Marvine Elementary School implemented a First in Math online learning block from 2:45 to 3 p.m. every day for the past three years. Short time segments are recommended for effective practice without taking up mathematics instructional time (Van de Walle, Karp, & Bay-Williams, 2010). The students used their own laptops and their successes were automatically recorded and were celebrated with public recognition on a bulletin board in the hallway of the school. Marvine's goal for instruction and learning is to develop "more involved thinking," said 4th grade mathematics teacher, John Phillips. This goal matches the working definition of computational thinking in this study.

The FIM online program offers a substantive content that supports any core curriculum with eight Skill Set Groups, bonus games, and a full range of skill-building activities for grades 1-8. Most recently, a programming component has been added to the First in Math online program called Computational Thinking (CT) World.

RESEARCH METHODOLOGY

Standardized test data were collected from school district and the Pennsylvania Department of Education test scores to report on the outcomes of the FIM program at Marvine Elementary. Also, data was collected from the Goals Index, providing specific student progress, which is set inside the FIM online program for each school and each grade level within the school. The Goals Index is a measure of a student's progress in four key areas on the FIM Online program: 1) activity—a measure of persistence in mathematical thinking; 2) fluency--mastery of all four operations in whole numbers (1 to 12); 3) word problems--ability to solve word problems in nine categories (at grade level); and, 4) procedural fluency--ability to solve multi-step and open ended computational problems.

RESULTS

Trends of the Data. Marvine Elementary School in BASD faces many challenges with struggling and at-risk students, students of color, special needs students, and English learners. Despite these challenges, Marvine Elementary succeeded in increasing its goals index this year.

The success of the First in Math online program is reflected in a letter (J. Silva, personal communication, November 8, 2018) to Sun from Jack Silva, BASD assistant superintendent and chief academic officer, he stated:

FIM is making a significant impact on BASD students' math fluency skills. This digital platform is efficient, affordable and scalable. It is highly engaging for our students and is a valuable tool for our teachers to monitor their growth over time.

We have, in the past two years, exceeded the fluency goals we set for all. For 2016-2017 our goal was to have 70% of all third-grade students' master addition and subtraction skills using FIM's VIFs modules. By June 2017, 82.6% of our third-grade students proved competent in their ability to add and subtract any two double-digit numbers.

In the 2017-2018, 93.4% of third grade students mastered addition and 84.8% mastered subtraction. In this second-year implementation, the fluency goal was extended to include fourth grade students mastering multiplication skills. By June 2018, 73% of our fourth-grade students were able to multiply any two double-digit numbers.

Our current third-year implementation goal is for fifth grade students to master division. The strong and consistent academic achievement demonstrated by the students is supported by the scientifically based and pedagogically solid approach to learning of FIM's design.

The power of a clear goal, effective instruction, formative assessment, and this self-pacing learning tool makes FIM an indispensable factor in our math program's success. VIFs completion certificates and the FIM Family Link feature enable us to maintain visible and positive outreach in our community.

Similarly, in a letter (J. Roy, personal communication, January 6, 2020) to Sun from Joe Roy, Bethlehem Area School District Superintendent stated:

The First in Math platform contains myriad standards-based, digital mathematics games that engage our students and build a love of math. FIM gives BASD students a continuous experience of success and increased confidence that

insures they spend a lot of time thinking mathematically. Each year, BASD elementary students solve more than 50 million math problems on FIM for sustained, deliberate practice. The program has become part of the culture in our 16 elementary schools.

In our first year, we focused on our third graders and asked them to master the tasks on the Very Important Facts Module. At the end of the year, 82.6% of all third-grade students had mastered adding and subtracting two-digit numbers. As this cohort moved into fourth grade, the goal was extended to mastering multiplication and division.

Going forward we have expanded fluency goals - all four operations to be mastered by at least 70% of our students completing fourth grade. For fifth grade the bar is raised to students mastering decimals and fractions.

With FIM's Goal Index feature, the challenging and self-pacing content enables us to set and monitor goals achievement in four key areas: sustained math practice; fluency; procedural fluency; and word-problem-solving skills. First in Math has proven to be a trusted partner in helping us to move the needle in mathematics achievement for all of the students in our diverse district.

According to the BASD superintendents, the FIM online program provided a framework for mathematics curriculum goals and contributed to the district's improvement of their mathematics achievement scores.

Table 1

Marvine Elementary Goals Index 2017-2018

Grade: School Year: Phase:

Search:

School Name	Goals Index (out of 100)	Activity (out of 25)	Fact Fluency (out of 25)	Word Prob. Fluency (out of 25)	Procedural Fluency (out of 25)
James Buchanan Elementary School	64.5	25	18.7	9.9	10.9
Spring Garden Elementary School	62.1	25	19.0	9.2	8.9
Freemansburg Elementary School	60.3	25	20.1	6.9	8.3
Farmersville Elementary School	59.8	25	17.9	7.6	9.3
Asa Packer Elementary School	57.8	25	15.1	8.5	9.2
Miller Heights Elementary School	57.3	25	17.2	7.1	8
Hanover Elementary School	53.9	25	17.0	5	6.9
Lincoln Elementary School	53.7	25	17.9	5.2	5.6
Governor Wolf Elementary School	52.9	25	16.3	5.3	6.3
Fountain Hill Elementary School	51.2	25	15.1	5.3	5.8
Calypso Elementary School	49.4	25	13.4	6.3	4.7
William Penn Elementary School	48.9	25	16.3	3.4	4.2
Clearview Elementary School	48.4	25	14.8	3.3	5.3
Donegan Elementary School	46	25	14.2	2.7	4.1
Thomas Jefferson Elementary School	45.7	25	14.4	2.4	3.9
Marvine Elementary School	44.9	25	12.5	4.1	3.3

In 2017, Marvine Elementary School was ranked last among BASD's 16 elementary schools with a 44.9 Goals Index which includes 12.5 out of 25 for Fact Fluency, 4.1 out of 25 for Word Problem Fluency and 3.3 out of 25 for Procedural Fluency. Each area in the Goals Index--Activity-persistence, Fact Fluency, Word Problem Fluency and Procedural Fluency--contributes 25 points for a total of 100 points if all four areas are mastered.

Table 2

Marvine Elementary Goals Index 2018-2019

Grades 3 to 8 2018/2019 Elementary Search:

School Name	Goals Index (out of 100)	Activity (out of 25)	Fact Fluency (out of 25)	Word Prob. Fluency (out of 25)	Procedural Fluency (out of 25)
Marvine Elementary School	73.2	25	21.7	13.6	12.9
Spring Garden Elementary School	69.3	25	20.1	12.9	11.3
James Buchanan Elementary School	62.5	25	17.2	9.4	10.9
Asa Packer Elementary School	60.3	25	19.7	7.9	7.7
Hanover Elementary School	59	25	21.7	6.2	6.1
Clearview Elementary School	58.2	25	18.0	7.6	7.6
Freemansburg Elementary School	57.6	25	18.5	6.1	8
Calypso Elementary School	57.1	25	17.7	5.3	9.1
Farmersville Elementary School	56.7	25	16.2	7.4	8.1
...

Region: PA Inde Sch Sys District: Bethlehem Area School District School: Marvine Elementary School

Goals Index By Team

Grade: Grade 4 School Year: 2018/2019 Phase: Elementary Search:

Team Name	Class Name	Goals Index (out of 100)	Activity (out of 25)	Fact Fluency (out of 25)	Word Prob. Fluency (out of 25)	Procedural Fluency (out of 25)
dawn85pa	Math 04 - Phillips Jr - 3	100.0	25	25.0	25	25
togo87pa	Math 04 - Kukuvka - 3	93.9	25	24.3	22.5	22.1
river58pa	Math 04 - Amadoro - 3	59.7	25	18.4	9.6	6.7

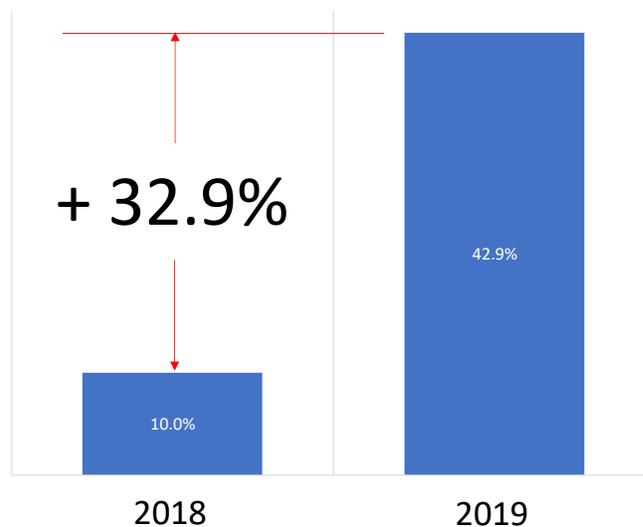
The Goals Index by the fourth-grade team shows classroom data for fact fluency, word problem fluency and procedural fluency. Fluency with basic facts (fact fluency) allows for ease of computation, especially mental computation, which supports the ability to reason numerically in every number-related area. Word problems require students to read and comprehend the context

of the problem, identify the question that is being asked, and create and solve a numerical equation. Many English learners have difficulty with word problems.

Procedural understanding is knowledge of the rules and procedures used in carrying out mathematical processes and, also the symbolism used to represent mathematics (Van de Walle, Karp, & Bay-Williams, 2010, p. 24).

Table 4

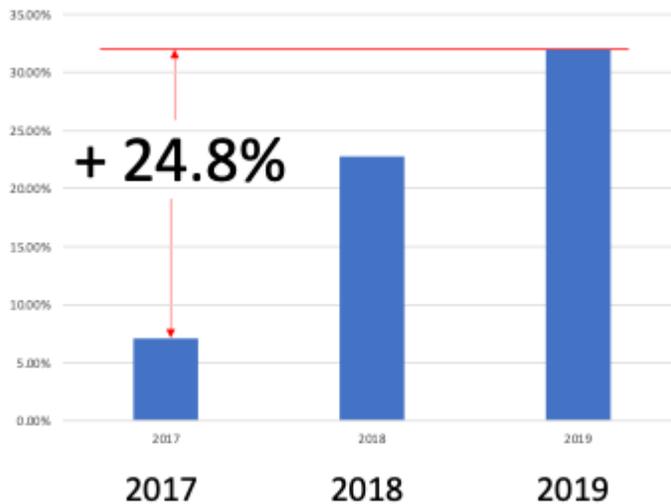
Marvine Elementary School Fourth Grade PSSA Math Scores



In 2018, only 10% of Marvine Elementary School fourth-grade students scored Proficient and Advanced on their PSSA tests in mathematics. In 2019, 43.9% of Marvine Elementary School fourth graders were able to reach those critical PSSA benchmarks, demonstrating a 32.9% percentage-point gain in the number of fourth-grade students able to score Proficient and Advanced over the previous year.

Table 5

Marvine Elementary PSSA Scores, 2017, 2018, and 2019



All grades in Marvine Elementary School had a 24.8% increase in students scoring proficient and advanced on the PSSA scores from 2017 to 2018, and this gain was maintained for 2019. Overall, this reflects a continued positive trajectory in mathematics achievement for Marvine Elementary School.

DISCUSSION

The researcher in this study investigated the students' thinking processes as they were engaged in the FIM online program and the effect of this interaction on their mathematics achievement scores as measured by the PSSAs. The students enjoyed their active engagement with the FIM online program and looked forward to the next opportunity to “play” again (J. DeStasio and N. Umbenhauer, personal communication, March 6, 2019). The students were motivated by earning stickers and other rewards within the FIM online program. The teachers believe that FIM is an amazing online learning tool.

The data overwhelmingly reflect positive outcomes when the FIM online program is implemented during the regular scheduled block of time. Table 1 illustrates Marvine Elementary Index Goal scores ranking at the bottom of all 16 BASD elementary schools. Table 2 illustrates

Marvine Elementary Index Goal scores ranking at the top. A contributing factor to the students' success is the ability of the online program to provide immediate feedback, along with setting a time limit, which has a powerful and positive impact on students' learning and improvement in fluency (Duhon, House, & Solomon, 2015). Also, the enthusiastic and supportive environment from the teachers, principal, and superintendents created a positive community of learners with similar goals.

Marvine Elementary School Fourth Grade (Table 4) had a 32.9% increase in students achieving Proficient and Advanced on Pennsylvania State Standardized Assessment (PSSA) from 2018 to 2019. The PSSA scores (Table 5) reflect a gain for the entire school from 2017 to 2019 of 24.9% for all students. A motivating and inviting learning environment with clear goals, allows mathematics students—even those who have many challenges—to gain significant achievement in mathematics.

IMPLICATIONS

Research into the First in Math online program suggests the students' use of this online program, along with a variety of approaches and a supportive classroom environment, can lead to significant improvements in mathematics achievement. As a complement to traditional instruction, problem solving and practice that is fun, motivating, and challenging invites students to notice and explore relationships such as problem decomposition, data representation, and modeling which are the specific components of computational thinking.

LIMITATIONS

This study was focused on one school at three different grade levels. More students and more schools may produce different results. This population of students brought challenges, such as poverty, English learners, single-parent homes, or both parents working long hours, to the classroom. Grade levels selected as participants for the study were third, fourth, and fifth; it is possible that other grade levels would produce different results.

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