AN ELEMENTARY/HIGHER EDUCATION PARTNERSHIP: ASSESSING STUDENTS MATHEMATICS KNOWLEDGE THROUGH TECHNOLOGY

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Abstract

A joint appointment Mathematics & Computer Science and Educational Studies Departments assistant professor and an elementary education teacher/adjunct professor collaborate on assessing students' mathematics knowledge through technology. The classroom teacher is completing action research in her own grade 2 classroom. The teacher assessed her students using the STAR Mathematics assessment during the fall screening and midyear for potential score gains, established intervention groupings, and analyzed potential student growth. She utilized software programs, Reflex Math and Prodigy, to strategically target fluency and conceptual math content for her students. This paper analyzes the progress of her students to date.

Rationale

Preparing students to compete in a global economy is an educator's job today. Students will be vying for jobs in a technological society. We need to provide students the opportunity to learn, practice and be assessed in mathematics using technology. Mathematics class is no different. The National Council of Teachers of Mathematics (NCTM, 2003) wrote, "Technology is an essential tool for teaching and learning mathematics effectively; it extends the mathematics that can be taught and enhances students' learning" in a position statement.

According to Allsopp et al (2010), technology has many benefits: explicitness, authentic contexts, allows students to test conjectures and modify understandings, facilitates higher-order thinking by circumventing, builds basic skill deficits, activates student response (engagement), provides [immediate] feedback, builds proficiency, communicates mathematical ideas, and makes cognitive connections. Even if a software program does not address all of these potential benefits, it would seem worthwhile to investigate the likelihood for success. Children of all ages could benefit.

Even at an early age students can readily access computers and feel a sense of pride (Clements and Samara, 2002). Technology can put students at the center of their own learning. In particular, adaptive technology programs assess the student's strong and weak math areas and readjust (Schaffhauser, 2013). Students who use mathematics software use prior knowledge to construct new math knowledge (Kirkiakidis and

Johnson, 2015). Software programs are essential tools to increase student achievement in schools today.

Using software programs that track students' progress allows teachers and students immediate feedback on progress. Students can self-assess mathematics content and skills they are struggling on, which areas they can improve, and where they are spending their time. Tracking progress can also help students set goals and interpret data (Schaffhauser, 2013).

Clements and Samara (2003, 2002) write that computers are catalysts for social interaction and emotional growth. They also found that computers are excellent tools for students with learning and physical disabilities. Technology can provide students with a sense of control [over their learning environment].

Where the computers are placed can add to the social interaction between students. Placing computers close to one another encourages children to share ideas (Clements and Samara, 2002).

Computers can be strategically used for Response to Intervention (RtI) to support struggling learners. Awareness of and attention to the student's instructional tier, differentiation anchors – time, intensity, explicitness, strategic instruction, and opportunities to respond, and math content should be considered when making decisions about which program to implement (Allsopp et al, 2010). The components of RtI are screening, progress monitoring, tiered math instruction, and family involvement.

Students who used computers during mathematics instruction were more engaged in learning math concepts and evidenced more self-efficacy than students who didn't (Kirkiakidis and Johnson, 2015). We are social beings and learn through interacting with others. Students who are more interested display more intrinsic motivation (Middleton and Jensen, 2011). Middleton and Jensen (2011) report inspiring and engaging students to sustain long-term motivation includes: technology, immediate feedback, encourage self-monitoring, safe place to make mistakes (Clements and Samara, 2003), work at the frustration level, use of adaptive programs (aligned to skill level), offer choice, build on prior knowledge (Kirkiakidis and Johnson, 2015), and confront misconceptions. Software technology during mathematics can offer all of these functions to engage and sustain learning learning. Clements and Samara (2003) also claim that computers during mathematics instruction increase fluency and deepen conceptual thinking.

Studies have shown that the combination of physical and onscreen manipulatives increase student achievement more than either method on its own (Clements and Samara, 2003).

Project

Funding was received through a Title IIA grant, entitled Depth Over Breadth Equals Student Success (DBSS) which includes approximately twenty urban elementary and middle level teachers over three years. The program was designed to: 1) strengthen teachers' knowledge base in mathematics; 2) model sound pedagogy and strengthen teachers' effectiveness for teaching mathematics; 3) establish grade level professional learning communities across the district; 4) develop a project within each professional group based on a needs assessment; 5) display projects in an online format; and 6) support teachers to be district leaders in mathematics.

The college professor provides access and opportunity for the teacher to receive mathematics content knowledge through summer workshops. On a weekly basis the teacher meets with grade level teachers from another elementary school in the district to discuss instructional approaches, create supplemental materials, and provide support to each other. The college professor provides the structure for teachers to meet, support on mathematics content questions that arise, provides supplies and materials for the classroom, and observes mathematics classroom providing feedback to teachers. The professor also observes classrooms to identify changes in classroom instruction and provide feedback to teachers.

Classroom Tools

Teachers have regular whiteboards, a document camera, and a projector in each classroom. Three-five computers are organized in a group for learning centers. Students in grades 3 and 4 have personal Chromebooks. However, in grades 1 & 2 there are five Chromebooks and five IPADs available for classroom use.

Curriculum

The district adopted Engage NY Mathematics curriculum in grades K-6 during the 2015-2016 school year. Eureka materials published by Great Minds were purchased for all teachers and students. The teachers in DBSS were part of a pilot program during the 2014-2015 schoolyear. They met on a weekly basis to discuss the mathematics curriculum with other grade level teachers. The DBSS participants also received classroom supplies and materials to support mathematics instruction.

Study

The following study addresses the needs of grade 2 students in an urban elementary school in Rhode Island. The focus is on these students math learning needs through instruction and assessment. The teacher administers a benchmark assessment three times per year. She follows the district curriculum for grade 2 mathematics. She also employs software programs to provide stimulation to students while learning mathematics facts and increasing conceptual math knowledge. These tools provide her with formative assessment to group by ability for math intervention.

Research questions

How do we use assessment data to inform instruction?

In what ways, if any, do software programs assist with improving students mathematical fluency and conceptual knowledge?

In what ways do software programs promote student engagement and increase mathematics discourse among students?

Participants

This grade 2 classroom was designed for dual language students where some subjects are taught in English and others in Spanish throughout the school day. Mathematics is taught in English, however last year it was taught in Spanish. The students in this class are 100% Hispanic and 100% receive free lunch. Ten students are boys and 9 students are girls.

There is one bilingual certified teacher with a Masters in Teaching English as a Second Language. She also teaches at Rhode Island College as an adjunct instructor.

There is one teacher's assistant (TA) for forty minutes daily for mathematics intervention. She provides one-on-one or small group interventions developing mathematical fluency.

Methods

Mathematics instruction occurs daily for 1 hour and 30 minutes and includes direct instruction with modeling, independent work (e.g., sprints: fact fluency), pairs, small group, and whole class methods. The mathematics intervention is scheduled for 20 minutes daily. Students use mathematics manipulatives (e.g., base 10 blocks, place value cards, fraction tiles) and online software programs to strengthen fluency and build conceptual understanding. The teacher employs a variety of instructional strategies demonstrating math content on the document camera (Elmo), increasing math vocabulary through video and songs, using gestures and chants (e.g., "oops we have to regroup"). There are typically five math learning centers to include small group targeted intervention with the TA, small group with the teacher, independent work, computer center for intervention, and Chromebook.

Three online assessment tools are employed during mathematics instruction in this classroom. The first is Renaissance Learning MATH STAR, a benchmark assessment tool administered three times a year (fall, winter, and spring). STAR is aligned to grade level mathematics content standards. Students are rated overall in four categories: "At/Above Benchmark," "On Watch," "Intervention," and "Urgent." Each time a student takes the STAR assessment, he/she receives an overall rating. Additionally, teachers can drill down to individual standards to identify strengths and needs of each student. This tool also provides meaningful information for the teacher to develop intervention groups. Table 1 identifies the categories that students are placed based on their achievement.

Table 1 - STAR Cut Score

- The number of categories, the category names, and the minimum proficiency level chosen create a *benchmark structure*. There are four default categories, but the number of categories in the structure can be changed from two to five.

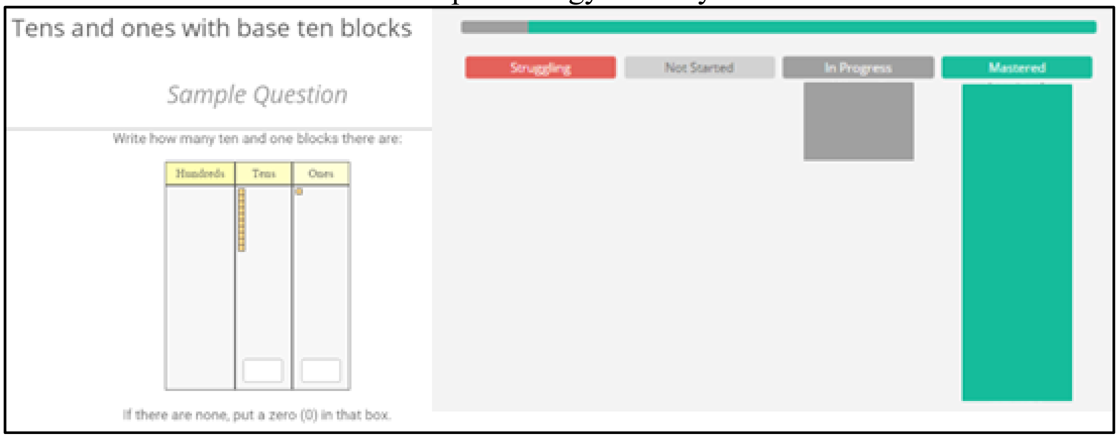
Category	Description	Default Cut Score
At/Above Benchmark (green)	Students meeting or exceeding the benchmark score	At/Above 40 PR
On Watch (blue)	Students slightly below the benchmark score	Automatically calculated as the range between "At/Above Benchmark" and "Intervention"
Intervention (yellow)	Students below the benchmark score	Below 25 PR
Urgent Intervention (red)	Students far below the benchmark score	Below 10 PR

The second program is called Reflex which is designed to improve fact fluency. Students will be able to develop deeper content knowledge when fact fluency is strong. Reflex begins with math fact review and then includes mini lessons targeted based on student performance. There is also a "play" component which reviews fluency facts they have already mastered. This keeps the students engaged and motivated with immediate positive feedback. There is also a Spanish version for the non-English speakers. The lesson adapts to the students skill based upon the prior practice time.

The third program for mathematics is Prodigy. Students with weak areas targeted as in need of urgent intervention in the fall screening MATH STAR assessment had 1st grade assignments on Prodigy. Prodigy is adaptive and will adjust the math problems based on the student's response.

Students can also compete against each other in a "battle." This particular aspect of the program has motivated a number of competitive students. Each student continues to receive questions based on their level. Students continue to work on different math skills based on their performance in the program. Student progress is reported to the teacher in four categories: struggling, not started, in progress, and mastered. The math problems that students encounter include virtual manipulatives as seen in Table 2.

Table 2 - Sample Prodigy Activity



The teacher attempts to address all types of learners through visual, auditory and tactile methods. She agrees that differentiation is important to ensuring success for all students (Andreasen and Hunt 2012). One benefit to using online programs is that the teacher can tailor assignments to address specific student needs. Additionally, the online activity fills in the gaps of mathematics knowledge and comprehension of content. They are also fun and motivating. Technology can provide constant monitoring and revision as it is a fluid dynamic process. Technology implementation also supports students' multiple intelligences, specifically visual auditory (Garner, 1993). It further facilitates the learning modalities of visual, auditory, and kinesthetic learners.

Technology serves a dual purpose in the classroom. It is the medium by which students can be formatively and summatively assessed, as well as it can provide students with interventions in the form of targeted practice. It reinforces the concepts and skills students have already been taught in the classroom, and for those students who have demonstrated mastery in such areas, it provides a more enriched exposure to concepts. The programs used meet students where they are, no matter if they are at opposite ends of the spectrum. It provides differentiation in the form of scaffolding for the students who have gaps in their skills and content knowledge and continues to build on the strengths of students that are on level or above level.

This type of differentiation provided through technological resources occurs on an individual student basis as well. For example, if a student is on or above grade level in the domain of Operations and Algebraic Thinking, the program provides that student with advanced grade level work in that area, or it builds the students' strength in an area that they make be lacking, such as Geometry.

This is important because in the curriculum maps that we use, a topic like Geometry is taught at the end of the school year. Online programs such as Prodigy Math encompass all of the Common Core Standards. Although the teacher hasn't covered the topic of Geometry yet due to the progression of the curriculum, students are exposed to those concepts through the online program. This builds students' prior knowledge in that area. Therefore, when the teacher introduces the concepts of Geometry, some of the students will have some background knowledge and have a "head start" on what will be covered. In addition, students who have achieved 100% fluency in addition and subtraction according to the Reflex Math, have been promoted to the multiplication fluency portion of the program. At the same time, students who haven't mastered fluency in addition facts, continue to receive remediation through the online program.

Websites and applications benefit students in numerous ways stated above, however, it can't replace the prompting and questioning by teachers that enable students to explain their reasoning and mathematical thinking, as emphasized in the 8 Standards of Mathematical Practices (Common Core, 2009).

Low socioeconomic students may not have access to technological devices at home. Used in meaningful ways, computers can motivate and help students feel confident enough to take risks. They can answer a given question on an online program without the fear of being made fun of or ridiculed by peers if incorrect. It provides students with an environment which allows them to feel comfortable and lowers the affective filter.

Students have the capability to listen to a question read and repeated as many times as they need. Teachers can't always meet with each student 1 on 1 or provide instant feedback to each individual student. When students log-on to the sites, it's as if they have a personal teacher assisting them in their learning and giving them instant feedback.

Classroom observation

After a mini lesson of direct instruction, students divided up into 5 centers. One included a center activity with 4 computers grouped together. Students were to log on to the Reflex site and work on the assigned math practice and activities. Each student worked on the lesson that was assigned to them. The problems appeared to be similar, yet not the same. The topics varied with addition and subtraction of single digit numbers (e.g., 1+5), doubles (e.g., 2 + 2), and zero (e.g., 0 + 4). One girl explained to a boy in Spanish how to access and answer the math problems online. After some conversation back and forth, they both continued with their work. Students would help each other by explaining directions or assisting one another with the computer work. There appeared to be an environment of student to student support. The teacher was with one group at the math support table to reinforce the math lesson. A teacher's assistant worked with a small group of students in another corner. The focus was skip counting by 2's or 10's to support fluency development. Other students worked independently with Chromebooks or math worksheets on assignments. Students visited three centers during this block of time.

Results

The teacher administered the fall and winter MATH STAR and analyzed student progress. Students made gains on the MATH STAR from the fall screening to midyear. There was a 23 % learning gain for the entire class on average. Overall, 38% of the students improved by 1 category and 28% improved by 2 categories.

Delving a little deeper into the domain standards of Numbers Base Ten, the student group ratings are either "Above," "Within," or "Below". On the fall MATH STAR data on the Common Core State Standards Math (CCSSM) Understanding of Place Value (2.NBT.A), student scores went from 84% below grade level in the fall to 32% on the midyear. Additionally, 16% were within or above in the fall and 68% midyear. Tables 3 & 4 below represent the 2.NBT.A data with student progress.

Table 3 - CCSS Math 2.NBT.A Screening

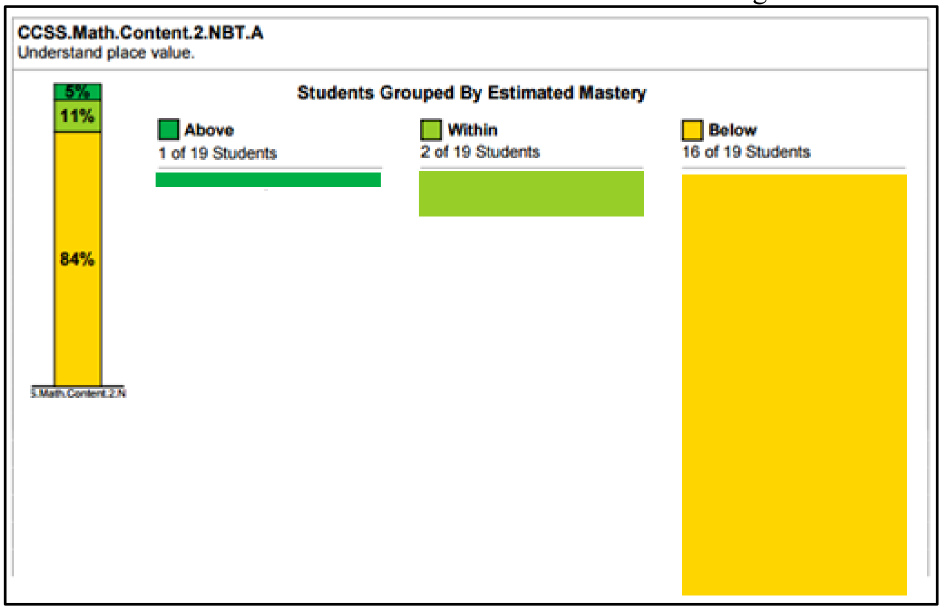
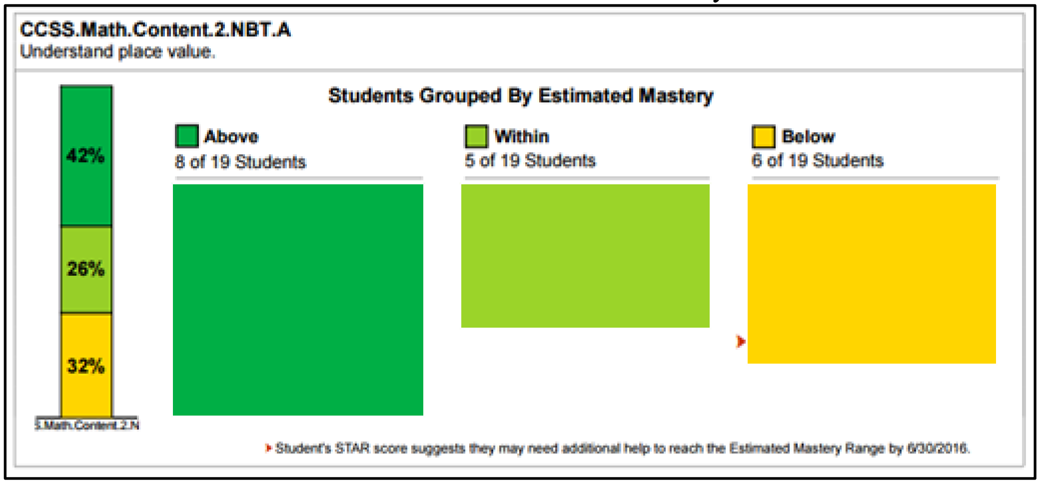


Table 4 - CCSS Math 2.NBT.A Midyear



On the CCSSM Understanding Place Value and Properties of Operations to add and Subtract (2.NBT.B), student scores went from 95% below to 53% below. Five percent of the students were above grade level in the fall and 47% were within or above midyear. Tables 5 & 6 below identify which students need more support on these standards.

Table 5- CCSS Math 2.NBT.B Screening

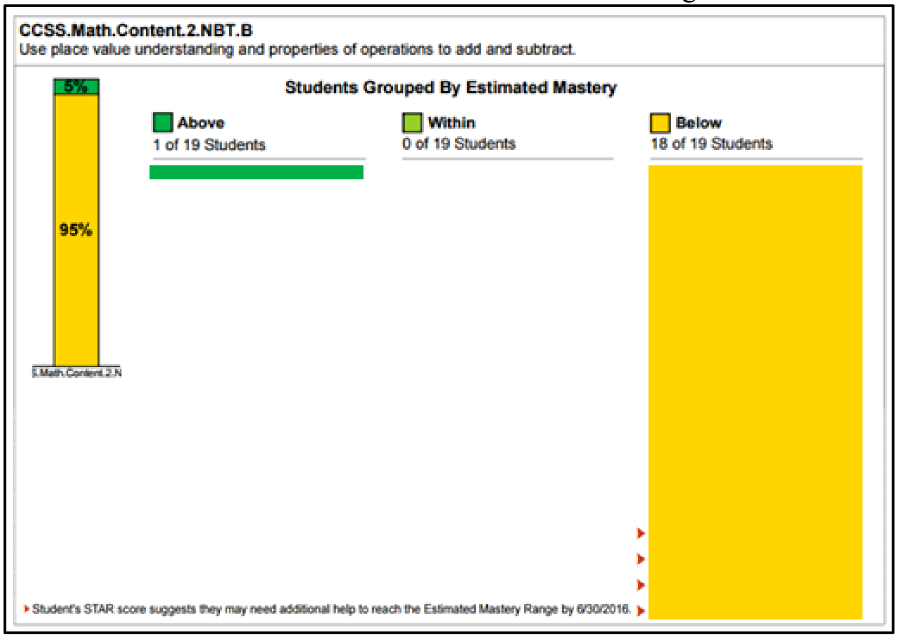
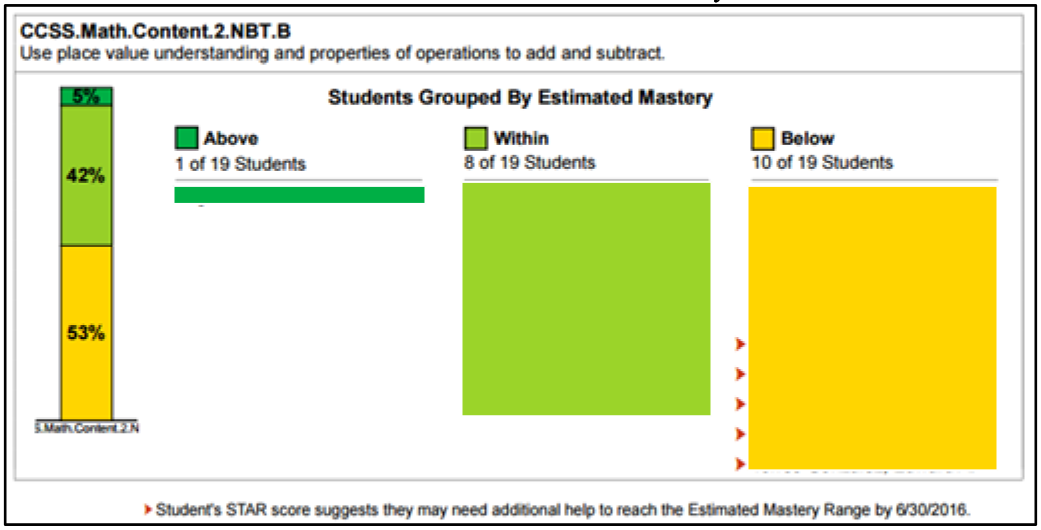


Table 6 - CCSS Math 2.NBT.B Midyear



On the CCSSM Add and Subtract within 20 (2.OA.B) 21% of the students were below grade level in the fall, and only 5% below midyear. Seventy-nine percent were within or above grade level in the fall and 95% were within or above mid-year (see Tables 7 & 8).

Table 7 - CCSS Math 2.OA.B Screening

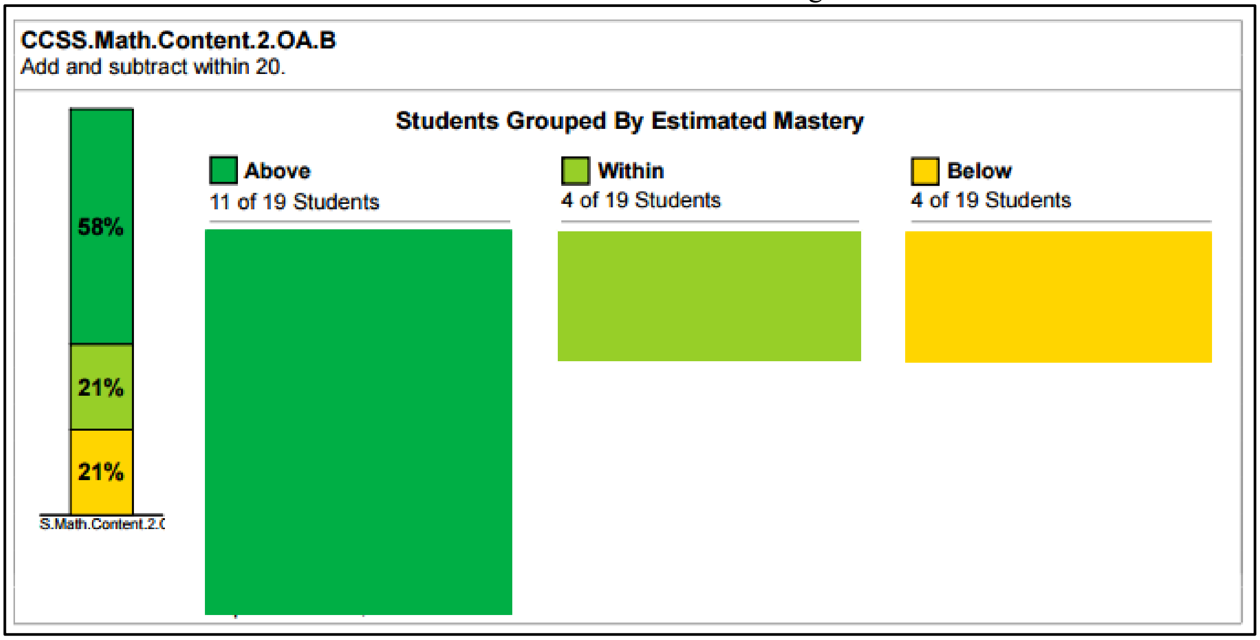
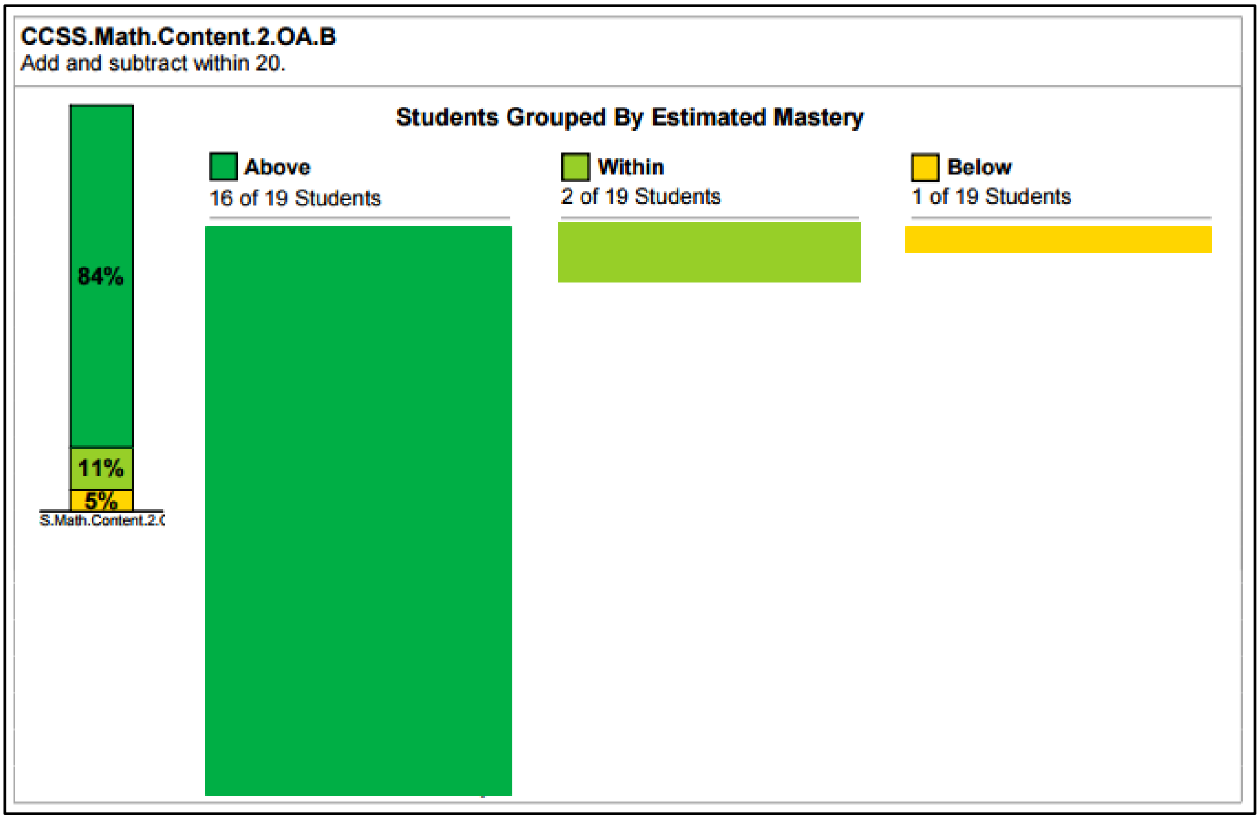


Table 8 - CCSS Math 2.OA.B



It appears as if students in this class have made progress on the grade 2 CCSS place value standards on the MATH STAR assessment. To what degree would require further statistical measures.

Findings

How do we use assessment data to inform instruction?

Using data to inform assessment is necessary for educators today to try to meet the needs of all children. This teacher uses formative and summative assessment to provide the means to meet the diverse learners' needs in this classroom. The MATH STAR provided Benchmarks results multiple times per year to identify those students in need of immediate intervention. Prodigy and Reflex Math allow students to move at their own pace through adaptive math activities that are engaging and motivating. It also affords an opportunity for advanced students to move on to more challenging mathematics content.

How do we use assessment data to inform instruction?

The teacher can tailor her small group instruction around deficiencies identified in the software reporting systems. Results are quick and effective at assessing students' lagging skills. The teacher can react immediately to remediate misconceptions and issues with students' conceptual understanding. Physical manipulatives can also be used to reinforce concepts.

To answer the third research question: *In what ways do software programs promote student engagement and increase mathematics discourse among students?* a more observational approach is utilized. Although anecdotal evidence is provided to answer this question, it is powerful nonetheless. The engaging online format of Reflex Math and Prodigy provides the impetus for students to work on math even when the teacher didn't make it a must-do activity. Students choose to spend time on math websites. They find it fun! In turn, it is meaningful to them. It also provides students practice adapting to their performance providing instant feedback. Students with limited English proficiency, who often shy away from answering questions in a whole group setting, can input their answers on the computer program without the fear of being wrong in front of the entire class. As the students use headphones while using the computers on an individual basis, the feedback they receive from the computer program is confidential. Therefore, they are more willing to attempt to answer questions in this way. They feel proud of themselves when they achieve or pass a level or get a certain score. Students show progress and the program provides them with positive reinforcement. The programs create certificates and parent reports, which is an excellent way to keep parents informed of their child's progress in specific areas.

Students help one another in English and Spanish. It creates a community classroom environment where students feel in charge of their learning and responsible to support one another.

Limitations

Due to the fact that mathematics instruction for dual language classrooms rotates, students may not progress as quickly as other students. Although students this year are being taught in English, their prior year, mathematics was taught in Spanish.

This is one classroom with one teacher in one school. This teacher devotes 90 minutes to mathematics each school day. This may not be possible for another classroom teacher.

Implications

Although it is just half way through the school year, the teacher is pleased with the progress of her students and their engagement during mathematics class. Realizing that each group of students is unique and not all may be motivated by online math activities, being flexible and using a variety of strategies is always good instructional practice. This teacher feels more confident in her students' math fluency and conceptual knowledge as a direct result of Reflex and Prodigy software programs.

In closing, many aspects of the classroom experience are not tangible or identically replicable. There is a "je ne sais quoi" that effective teachers possess which is not always definable. Therefore, the lesson delivery may differ with another teacher. Comfort with the content is an important aspect and willingness to try new strategies for student success is important.

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