White Paper

Math Whisperer

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Introduction

The Math Whisperer approach to mathematics offers an intervention program for students who struggle with math and/or are behind their grade level peers in mathematical achievement. Based on nearly twenty years of hands-on research the approach has been refined into its present state. We call this present state our *Research Edition* and given its efficacy in classrooms chose to make it available to schools in a paper-based commercial package in the summer of 2015. In the meantime efforts to offer an online component have begun and will be completed in the next twelve months.

Math Whisperer is based on a developmental approach to mathematics that prioritizes specific mathematical concepts over all others. Over time and after much research as well as trial and error, approximately eighteen Critical Building Blocks (CBBs) were identified for their capacity to serve as a mathematical foundation. The hypothesis that these are in fact true CBBs has been proven repeatedly through research that showed the positive effect on a student's learning (Vanchu-Orosco, 2014). As CBBs that were missing from a students' understanding of math were learned the learning led to gains that were often substantial. In fact, gains on standardized test scores for students identified as being below grade level in math were often the equivalent of two to three grade levels after just a six month program that supplemented a student's normal math sequence (German, Bruckhart, and Kiplinger, (2008), (Toker, Green, Vanchu-Orosco, 2014).

Math Whisperer is unique in its approach and the results produced.

Approach

A number of countries have accomplished significant mathematics gains in recent years through a focus on a few concepts with depth of understanding as the goal (Hammond, 2014; Schmidt, 2008). In the U.S. the paradigm for the past twenty years, including the recently developed Common Core, is *coverage* (Tanner, 2013) The irony here is that the U.S. constantly touts the notion of depth over coverage, citing examples such as Singapore and Finland as obvious examples, but then the power of inertia generally returns us to coverage as the basic model of teaching and learning. Even the flatness of test scores that has occurred in the last ten years has not yet been enough to compel a wholesale change (Hammond).

This notion of coverage leads to curricula that assign a time component to learning the material in each state's standards. This is both an artifact of the coverage model, but also a practical consideration given that if some x number of topics must be covered and all are viewed as equal given that all represent potential test items on the end of year test, then x ÷ the number of days in school becomes a practical way of parsing the material. However, this model ignores the fact that some topics are simply more important than others and that without them additional learning in any environment will be difficult.

The identification of Critical Building Blocks (CBBs) is the key to understanding the components of a mathematical education that are the most critical for students to have mastered. Central to the Math Whisperer approach has been a systematic ferreting out of these critical components from among the full range of grade-level math standards across the country. The approach, explained in greater detail in a later section, helped us to identify the CBBs that would eventually become the heart of the Math Whisperer approach.

Once the CBBs were identified the next step was to identify when and how each was taught as well as to ascertain which students possessed them and which did not. This is the stage when a number of issues began to present themselves as obstacles to prioritizing the CBBs in classrooms. First, what quickly became obvious was that that the strongest match between each CBB and a state's standards was often in standards from a grade several years prior to the identification of a learning gap involving that CBB. Second, when the CBB was introduced as a standard it was almost always within a topical list of standards to be covered, not in a prioritized list of things that require mastery in order to be successful at math. And third, in most cases the CBB was also not a specific component of the standards at the grade level where the gaps were being identified, and yet the grade level material presumed that the student possessed the CBB.

This step showed us that through no fault of their own teachers are actually prevented from teaching the CBBs at the depth required to generate understanding, *both* at the grade level when a form of the CBB first appears, *and* in the current year of instruction. This happens due to the coverage model that makes it difficult to prioritize any one concept over another, even when it can be shown to be the best possible choice for a student. This is clearly a frustrating predicament to those who teach that on the surface doesn't offer a simple way out.

The Math Whisperer approach tackled the problem this way: identify the CBBs a student is missing, teach students to master a missing CBB through supplemental activities that focus exclusively on the CBB, and then move on to the next until each of the CBBs are in place. This approach allows a teacher to meet the practical demands of delivering on a grade level curriculum while also supporting students with the foundation they need to be successful in math. It enables any teacher in any school to ensure that when gaps in the CBBs exist the teacher has a way to identify and remedy them.

Math Whisperer works by using a simple survey with a high correlation with the presence or absence of a CBB to identify missing CBBs and create an individual supplemental plan for each student. The plan points towards specific CBB lessons that focus on creating mastery of the missing CBBs. Over the last several years the survey and the CBB lessons have gone through a number of revisions to ensure that each is capable of playing its assigned role in the process.

After years of working with the Math Whisperer tools the conclusion we came to is this: mathematical achievement can happen at a greater rate and with less effort than what we've become accustomed to over the last thirty years. The Math Whisperer approach showed that students who struggle could be brought to grade level at a rate of two to three grade levels a year, even for those who are severely behind. But it also showed that even though we presented Math Whisper as a remedial tool, its efficacy among students identified as high performing led to benefits even for them. Thus a misidentification results in a positive for the student, making it unique in the remedial landscape.

In short, the approach showed a very promising answer to a problem that has persisted now for a great many years, all within the current educational landscape.

Outcomes

Measurements of the outcomes of the Math Whisperer approach have occurred in a variety of ways, from ad hoc analysis in early pilots to rigorous statistical evaluations of various efforts. We offer a brief summary of these efforts below.

Many early pilots and many of the implementations since simply compared pre and post data and performed an ad hoc comparison to the overall population. In virtually every instance the results appeared to be overwhelmingly positive, and since Math Whisperer was the single intervention it was reasonable to infer that it was the Math Whisperer approach producing the effect. While caution must be exercised in interpreting such results given the lack of rigor in many of these analyses, the success of students in the programs when compared to what would otherwise have been expected of them was very encouraging.

More advanced studies such as one conducted at Patonville School District in Patonville, MO in the 2006-2007 school year approached a randomized control study in that middle school students were selected into various conditions by classroom/teacher that included no intervention and full teacher support. The Patonville study and a number since show that students receiving the intervention achieved gains on standardized tests scores following a five and a half month intervention that were more than double the control group. The only difference between the two groups was the addition of the Math Whisper approach.

The 2006-2007 school year was also the first when we conducted studies that attempted to understand the effect of the Math Whisperer approach on state test scores. A study at Lincoln high School in Denver showed a dramatic increase on state test scores of students who participated in Math Whisperer. All students in the pilot had previously scored "low unsatisfactory" on the Colorado state assessment administered at the time (CSAP). The average scale score growth on CSAP for students in the pilot was 45 points compared with their peer group state average, which was 14 points.

In 2007-2008 70% of the high school students in a pilot again at Pattonville School District using the Math Whisperer approach showed significant growth on their Math MAP (Missouri Assessment of Progress) index scores compared to only 30% of students in the control group. As in virtually all the other pilots the intervention lasted for five months and supplemented the regular instructional program.

In 2014 doctoral students at the University of Denver conducted a meta-analysis of some of the earlier pilot data to subject them to a more rigorous analytical approach. The idea was to determine if the gains seen by students were being properly ascribed to the intervention. Their conclusions were indeed that students who are behind grade level experience on average two to three years of growth in a five and half month intervention of the Math Whisperer approach, and that Math Whisperer provided a benefit even for students who were deemed to be on grade level (Toker, et. al.).

One additional effort is also worthy of note. During the 2008-2009 school year Envision High Schools in the San Francisco Bay area asked us to focus on algebra-preparedness for students who were significantly behind their peers. At the time the 9th grade state exam was entirely algebra based. The pilot occurred at grade nine across four schools, two in San Francisco, one in Oakland, and one in Hayward. The intent was to understand the impact of the Math Whisperer approach with limited time and with only a small component of the program being deployed.

The result was that students grew one grade level, on average, between late August and February, as represented by NWEA MAP scores, which represented a significant improvement over the growth during the entire previous year. The only change in the math program was the inclusion of several Math Whisperer lessons focused on algebra that were inserted into the regular math curriculum. The improvement among the students on the state test was from 5% of students scoring “basic” to 17% of students achieving the basic score far exceeding state averages for improvement.

Additional pilots and efforts since have shown the pattern regarding state test scores repeating itself in Missouri, California, and Colorado. In all these instances the common theme between the CBBs and the standards is their tie to the National Council of Teaching of Mathematics (NCTM) standards, which served as the foundation for each. Thus we feel confident stating that although we have not conducted formal studies in all fifty states, states that have standards that align with NCTM are highly likely to achieve similar gains. Our less formal work in classrooms when the approach was used as part of a normal course of study suggests this is indeed the case.

In summary, the Math Whisper approach with its focus on CBBs and the remedies for each qualifies it at the time of this writing as a promising program from a formal statistical perspective.

Identifying the CBBs

Identifying the concepts that now qualify as a CBB represented an iterative process. The methodology involved finding correlations between simple open-ended items and candidates for CBB status (Kiplinger, 2009). Identification of each CBB came from selecting those with the highest correlation coefficients with state tests and grade level norm-referenced tests. Once the correlations were found the items were used to identify gaps, which were then remedied with materials specific to that CBB. Once remedied the student was again tested to see whether the materials as designed were successful at inserting the CBB into a student’s mathematical repertoire.

In the end approximately eighteen concepts achieved CBB status. We say “approximately” given that our methodology never sought to “count” or “name” them. For example, what does one name the “thing” that exists when a student solves the problem, “what is 3 – 4?” and answers: “1,” or, as is often the case, “this is impossible”? Is it that they lack an understanding of negative numbers? Or is the issue that they are missing a property of subtraction?

Part of identifying a CBB involved administering the items to students who we knew had a partial understanding of the math that would be required to provide a correct response. For example, in the case of the item above we administered it to fourth grade students who had demonstrated their understanding of the idea that subtraction was not commutative (e.g., 4 - 5 is not the same as 5 - 4) but had no knowledge of negative numbers as those lessons were yet some years off. The most common response from these students was "this isn't possible." This allowed us to infer that when older students replied similarly we could assume that the issue to be remedied had to do with understanding negative numbers, not the fact that subtraction is commutative. For students who are severely behind grade level in their mathematical understanding, the answer of "this isn't possible" occurs regularly, and it was important that we validate what that response actually indicates.

To determine which items would be selected as representing the CBBs we started by selecting short constructed response items and then correlating scores with those of state tests and the off-the-shelf tests for which we had data. Note that we found data from adaptive tests, most notably the NWEA Maps test, to be the most useful in this regard given its ability to provide reasonably precise estimates of achievement regardless of how far above or below grade a student was. We began with the assumption that if we could identify the underlying constructs represented in the tests we would have identified the various possible CBBs.

Our first attempts at creating the assessment showed correlation coefficients (Pearson's r) that were at or about 0.6. While these were statistically significant they were not adequate for our needs. Subsequent improvements and modifications to the assessment led to correlation coefficients in the 0.9 range with 18 questions that took students five to ten minutes to answer (2009).

Our final assessment—a version of which we use to this day—showed a strong link between the 18 survey questions that took five to ten minutes to administer and nationally recognized commercial tests as well as state tests in middle and high school that took one to three hours of student time for math alone. This link is of particular importance, not only so that we can declare alignment with state efforts, but also because it shows that prioritizing the resulting CBBs will at some point have a positive impact on state tests scores, which absent a major policy change remain prevalent source of concern for schools, low performing schools in particular. We say "at some point" for the simple reason that while the Math Whisperer approach regularly produces the equivalent of 2-3 years of academic growth, some students are so far behind that it will take several years of interventions to achieve grade level.

Some have been critical that a ten-minute survey be used to identify the absence of a CBB. However, the nature of the items selected is such that additional items add little to no value to the precision in the estimates until the number of items approaches that of traditional standardized tests, and yet the students are still directed towards certain CBBs in an almost identical manner. The increase in the statistical precision of an estimate does not lead to a meaningful difference as to which CBBs a student will be directed towards. We choose not to burden the student or the classroom any further than is absolutely necessary in order to obtain the data we need to target specific CBBs.

An interesting but unintended outcome of how the assessment was created is that if we chose to we can predict student scores on state tests, even from a test that takes just five to ten minutes. We do not formally report the predicted scores as doing so detracts from our overall mission and as is generally the case, scores with a predictive value in today's world are often over or misinterpreted. Nevertheless, it speaks to the technical quality of the assessment.

Filling Gaps in the CBBs

The Math Whisperer program is designed to be supplemental to regular classroom activities. The approach recognizes the practical difficulties of substituting material in a current year's standards with material that appears for all intents and purposes to have come from a prior year. The Math Whisperer approach has been shown to have the greatest effect when teachers embrace the idea that as students master the missing CBBs it will make the present instructional environment that much more meaningful and effective.

From a pedagogical perspective Math Whisperer materials have been designed both to engage and respect the student. It is one thing to "remediate" a student and quite another to support a student in their effort to learn. The materials were designed to meet each student at their current level of understanding so that they can experience success at the outset, and then continue that pattern throughout. The materials are intentional in fomenting the belief in each student that they really can be successful in math. In interview after interview with teachers and students a common theme was that students who viewed themselves as failures in math at the start of the program changed that view to one of belief in themselves as capable math students who expect to understand math.

To supply a student a missing CBB the Math Whisperer team created unique lesson sets for each CBB designed to develop a deep conceptual understanding of the CBB within the student. Each time any concept is introduced the process follows Piaget's model of true understanding being built through the process of:

Concrete objects → Pictures → Abstract notation

Each new component of a CBB is introduced to the student with concrete objects, also known as manipulatives in math education parlance. Students eventually move on to pictographic representations, using some that are provided for them but also learning to draw their own. In the end, students come to understand the meaning behind the abstract notation, or symbols as they are more commonly called, since it is at that level that most academic math is performed and students will be expected to excel at the notational level. This process is repeated over and over within each lesson set.

Practice that is designed to deepen the student's understanding accompanies each activity. All activities and practices are designed for the student to do without teacher or parent modeling. This leads to independent thinking and confidence on the students' parts. The activities and practices are specifically designed to be accessible to the student. Teachers can and should be active supporters, but for students who are behind their peers the more the student comes to see him or herself catching up, the more likely they are to continue down that path.

Validation for each of the lessons was accomplished through a variety of analyses. Pre and posttest results from parallel versions of the diagnostic showed evidence for when a gap had or had not been filled. Validation efforts included a brief analysis that showed that the results on the posttest were not random, i.e., it was important to note that when a student had not received instruction on a missing CBB that the student still shows a gap regarding the CBB. This would provide validity evidence that the absence or lack of the lessons being applied was a significant contributor to the result.

Perhaps one of the greatest arguments for the validity of the lessons as being capable of promoting the desired learning is in the evidence presented by students who were identified as being at grade level and still were steered into one or more of the lesson sets for a variety of reasons. Just like their underperforming peers, these students also experienced growth as represented in both off the shelf and state test scores.

Finally, we would again be remiss to suggest the Math Whisperer approach can remedy all CBB deficiencies in all students in a single year. The data suggest that for a majority of students performing below grade level it is reasonable to expect 2-3 years worth of growth on a standardized test, with a meaningful impact on state test scores as the student approaches grade level understanding. For some students who are severely behind, reaching grade level will require multiple years of effort.

Implementation Fidelity

During the pilot phase several observations regarding implementation were made that are worthy of note. They are as follows

1. The mode of implementation mattered far less than the fidelity to the model. The model is designed to repeat the process of moving from concrete objects to pictographic representations to abstract notation over and over again, each time a new concept is introduced. Whether the fidelity to the model was obtained via homework assignments or classroom work, it was that fidelity

that proved to be the key to success. Teacher enthusiasm for the model and the approach was a strong indicator of the degree to which students took the model seriously.

2. For adults trained in mathematical education implementation presents a unique challenge given that a number of the CBBs address topics most at the middle and high school levels would consider as basic, or even rudimentary. Some during the pilot phase even took this as a slight, something that somehow put them into a negative light. Math Whisperer was created as a tool to support teachers as they work with students who are severely behind their grade level peers, not as a mainstream mathematics program. This is something for anyone working with the Math Whisperer approach to keep in mind.
3. The more we worked with students who struggle with math the more we came to see them as "honest" learners. What we mean by this phrase is that the struggling students seemed to distrust the approach to math presented them in their textbooks. The fact that it did not make sense to them meant, at least to them in their minds, that the approach was illogical and therefore not to be trusted. Our approach, we discovered, dealt with this issue head on. Working with concrete objects, for example, allowed students to see that the underlying math isn't some trick, but rather another way of talking about the world in which we live. While we are cautious about making empirical claims regarding the impact of developing such a relationship of trust with the students and the material, we have approached the development of all the materials with this idea of supporting the students in their desire to be honest learners.
4. The pace at which a student will move from the concrete to pictures to abstractions will vary according to the student. For example, in general, most students will spend a relatively small amount of time working with manipulatives during the introduction of a concept and then quickly move on to the picture phase, but for those who really struggle with a concept it may be that the concrete phase becomes the one in which the student spends the most time. The process phases as they are introduced in the lessons follow the following detailed steps:
    a. Students work with concrete objects to understand the basics of the concept.
    b. Students then quickly move into the iconic mode, working with the objects to create pictures of the materials.
    c. Students then work exclusively in the iconic mode, without the concrete objects.
    d. Students learn to translate the icons into symbols.
    e. Students leave behind the icons and work exclusively with the symbols.
    f. Students then use the symbols in a formal equation to draw a pictographic representation to show that the lesson sequence worked.

Summary

The identification of the CBBs along with the process of filling them as described in the Math Whisperer approach offer a proven methodology for supporting teachers in the improvement of academic outcomes. Empirical proof that CBBs actually exist and that their absence results in serious learning deficiencies for students is an exciting development since we can now identify such deficiencies and then immediately begin the processing of teaching them to a student.

The Math Whisperer program offers a practical approach to remediating deficiencies in mathematical understanding. The dramatic student growth of students who participated in the numerous pilots and studies to date is evidence that the approach is highly effective.

Bibliography

German, B., Bruckhart, G., and Kiplinger, V.L. (2008). Preliminary Evaluation of the Effectiveness of Peak Achievement's Math Intervention System at Lincoln High School, Denver Public Schools, Peak Research Internal Research Report.

Darling-Hammond, L., (2014). "What Can PISA Tell Us about U.S. Education Policy?," *New England Journal of Public Policy*: Vol. 26: Iss. 1, Article 4. Available at: http://scholarworks.umb.edu/nejpp/vol26/iss1/4.

Kiplinger, V., (2009). Properties of Peak Achievement's Diagnostic Assessment of Mathematics Gaps, Peak Achievement Research, Boulder, CO.

Scmidt, W. H., (2008). What's Missing from Math Standards? Focus, Rigor, and Coherence, *American Educator*, Spring 2008.

Tanner, J. R., (2014). *The Pitfalls of Reform: Its Incompatibility With Actual Improvement*, Rowman and Littlefield, Lanham, MD.

Toker, T., Green, K., Vanchu-Orosco, M., (2014). Evaluation Issues in Assessment: The Effects of a Math Achievement Program Based on Critical Mathematics Building Bocks, retrieved at https://turkertoker.wordpress.com/2014/10/06/effects-of-a-math-achievement-program-based-on-critical-mathematics-building-blocks-on-mathematics-test-scores-in-three-u-s-schools.

Toker, T., Green, K., Vanchu-Orosco, M., German, B., (2014). Evaluation Issues in Assessment: The Effects of a Math Achievement Program Based on Critical Mathematics Building Bocks, Poster, Monroe College of Education Research Methods and Statistics. AEA Conference, Denver, CO.

Vanchu-Orosco, M. (2014). Development and Validation of a Measure of Mathematics Deficiencies: The Critical Building Blocks Assessment. Research Proposal. Math Whisperer Archives.