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Literacy and Intervention

Academy of MATH®

Developing Mathematical Proficiency

Douglas MacGregor

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Research-Based Math Intervention

Academy of MATH®

by Douglas MacGregor

INTRODUCTION

The skills required to participate productively in society are ever increasing. Today's rapidly advancing technological environment constantly pushes the boundaries of what it means to succeed. The ability to think and reason mathematically is a critical factor for all students. And with the Common Core State Standards' (2010) emphasis on college and career readiness, educators need a way to provide solid instruction and substantial practice of basic mathematics concepts for all learners, so that they can achieve in school and beyond.

The *Academy of MATH*®, a research-based, online program, supplements and reinforces key mathematical concepts introduced in the classroom, and provides students with an opportunity to practice mathematical procedures using a variety of content and question formats. The program incorporates proven methodology and critical educational principles including mastery learning and student motivation. The *Academy of MATH* develops mathematical proficiency by focusing on conceptual understanding, computational fluency, and strategic competence across 10 mathematical subject areas.

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Instructional Methodology

Learning mathematics is a complex and time-consuming endeavor. For many students, mathematics is a frustrating and confusing array of facts, rules, and formulas. The confusion can often be due to the introduction of too many concepts in a short period of time. Students that do not have sufficient time to understand concepts, practice procedures, or solve problems are never likely to obtain a sense of "getting it." What's more, students that do not understand concepts, procedures, and problems rarely maintain the motivation to keep trying.

The instructional approach of breaking down component skills into manageable chunks, training students to a level of proficiency and moving them forward, celebrating each incremental step along a developmental continuum has proven to be effective in teaching struggling students. Once students have the necessary component skills, they can build up higher order skills.

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This effective instructional approach is founded on three distinct principles: it employs a task-analytic approach to mathematics learning; it is based on a "practice-makes-proficient" philosophy; and it incorporates a mastery-learning approach complete with positive and instructive feedback to encourage and maintain student motivation.

The Task-Analytic Approach

A central concept in the *Academy of MATH* is the use of task analysis. A task-analytic approach is essential in the training of complex skills such as reading and math, especially for students experiencing difficulty acquiring these skills. For students to overcome the significant challenge of learning a new skill, the coordination of a variety of cognitive

abilities is required; it is essential that the skill is broken down into its component parts, with each part representing a manageable chunk to be learned successfully (e.g., Browder et al., 2012; Jimenez, Browder, & Courtade, 2008).

Learning math is hierarchical in nature. As such, a task-analytic approach is appropriate for math instruction (Gersten et al., 2009; National Mathematics Advisory Panel, 2008). In the *Academy of MATH*, component skills of mathematics have been broken down and individually addressed, with students trained along a developmental sequence. This bottom-up approach gives students an opportunity to develop basic mathematical skills and knowledge before they move on to more complex or abstract mathematical concepts. Following a step-by-step, methodical approach provides students with the prerequisite knowledge to learn mathematics efficiently (e.g., Fuchs et al., 2008). Moreover, this approach gives students the opportunity to focus on conceptual understanding, computational fluency, and strategic competence. Once mastery of each component skill has been achieved, students are rewarded for their accomplishment and moved ahead to the next skill in the sequence. This approach ensures that essential foundation skills such as number sense and the base-10 number system are well established prior to introducing computation with whole numbers.

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Proficiency Through Practice

Another important feature of the *Academy of MATH* program is incorporation of a "practice-makes-proficient" philosophy. Educational research continually indicates that structured practice leads to development of accurate and fluent skills (Fuchs et al., 2010; Gersten et al., 2009; National Mathematics Advisory Panel, 2008). Indeed, instructional programs that do not provide sufficient opportunities for students to practice skills are unlikely to produce desired results (Fuchs et al., 2010). The *Academy of MATH* incorporates this philosophy, ensuring students receive sufficient opportunities to practice new skills.

A typical basal mathematics curriculum, on the other hand, uses a spiraling approach to instruction, where numerous skills are rapidly introduced in a single graded book and those skills may or may not be covered again in books at higher levels. Using this spiraling curriculum approach, basal instruction attempts to cover math topics in depth, but oftentimes in reality runs into the "mile wide, inch deep" problem, in which many different skills are taught quickly and superficially, and students are unlikely to fully grasp concepts or reach skill mastery. In an attempt to "get through the book" in basal programs, resulting concerns are a lack of adequate practice and review, unsound sequencing of problems, and an absence of strategic and step-by-step procedures for teaching problem solving (Schmidt, Houang, & Cogan, 2002; Snider, 2004). In the case of students with learning difficulties, research has in fact demonstrated that the typical basal math approach is especially detrimental (e.g., Bryant et al., 2008). The decision to "go on" when teaching mathematics to students with learning disabilities can produce devastating results. Since learning math is hierarchical in nature (new skills built on learned skills), students need to understand and master foundational skills before moving through the curriculum. Students who do not will continue to experience failure (Miller & Mercer, 1997).

The *Academy of MATH* progresses students through a sequence of exercises as they demonstrate understanding and proficiency. Students begin each subject area at each level with an instructional tutorial that discusses important concepts related to exercises they are about to begin. Next, students work with multiple-choice questions that focus on relevant mathematical language and concepts. Once they have demonstrated a high level of conceptual understanding, students are presented with fill-in-the-blank questions requiring them to perform an operation or calculation relevant to the subject area at that level. Students continue to carry out these operation questions until mastery is demonstrated. Once students have demonstrated their ability to compute at this

level, they progress to word problems requiring them to combine their conceptual understanding, computational fluency, and strategic competence to complete the questions. This step-by-step approach ensures that students develop essential skills and understanding because each small step is taught intensely with numerous examples and questions until proficiency is demonstrated. Students progress at their own pace; no student is held back to allow classmates to catch up.

Principles of Motivation and Mastery Learning

Another important attribute of the *Academy of MATH* program is the extensive use of motivational principles. In the *Academy of MATH*, each incremental success is recognized and rewarded; students continuously receive positive indications of progress and are continuously reminded of their learning goals and objectives.

The value of motivation when learning challenging skills cannot be underestimated; this is certainly true of mathematics (e.g., Cleary & Chen, 2009; Linnenbrink & Pintrich, 2002; Schunk & Zimmerman, 2008; Shores & Shannon, 2007). Compelling research exists, however, that shows many students in North America lack sufficient levels of motivation to allow them to succeed at math (Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007). Recent research (Gottfried, Fleming, & Gottfried, 2001; Gottfried et al., 2007) indicates that American children's level of enjoyment of mathematics tends to be high in the primary grades, but then falls dramatically as students progress into and through high school. To make matters worse, fewer and fewer students want to take more mathematics in school, despite feeling that mathematics is important. Coupled with the fact that many children do not possess the mathematical knowledge they need to function smoothly in today's technologically-advanced society, it is of extreme importance to design and deliver instructional programs that encourage and maintain students' motivation to learn and overcome challenges.

A particularly effective strategy to overcome the negative atmosphere that often characterizes complex skill development is known as Mastery Learning. Guskey (2007) describes Mastery Learning as a system where students are not required to do further work on a unit once they have been certified as mastering it. Students who do not achieve mastery criteria receive corrective feedback and continued practice until mastery is achieved. This method is effective in building struggling students' confidence, and developing intrinsic motivation and a willingness to take the risks necessary to reach challenging goals (e.g., Anderson, 1994; Guskey, 2010). Other researchers agree. Stipek and colleagues (1998) explain that, "a mastery orientation is associated with more positive emotions and enjoyment and few negative emotions, whereas a performance orientation is associated with more negative and few positive emotions and with less enjoyment" (Stipek et al., 1998).

The *Academy of MATH* utilizes a Mastery Learning approach. As students master a component of their training, they are presented with an award and printable certificate to demonstrate their success. Once a skill has been mastered, students move on to the next skill, a clear indication that a student is progressing. Students have concrete evidence of achievement that they can present to their parents, show to their friends, or display on a classroom wall. This positive reinforcement has a tremendous impact on building self-esteem and motivation. What's more, the short but intense training periods of 25 to 30 minutes allow students to stay focused without placing a heavy burden on their attention spans.

Feedback is another important part of the learning process. Without it, students would not know when they have performed a task adequately or not. Certain kinds of feedback, however, may be counterproductive to learning. For struggling students with a history of poor academic performance, negative feedback can be detrimental to perceptions of self-worth and self-efficacy. Alternatively, positive feedback can be motivating for struggling students. In addition, corrective feedback lets students know that they have not completed a task and provides them with information necessary to successfully

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complete the task in the next trial. Corrective feedback is supportive of students' learning needs and avoids the potentially discouraging effects of negative feedback.

The *Academy of MATH* only employs corrective and positive feedback. In the various exercises in the program, when a student makes an error, the correct answer is provided along with a step-by-step process used to arrive at that answer. This type of feedback ensures that an instructional opportunity is not lost. Congratulatory messages let students know when they have mastered each skill. This type of feedback encourages a positive atmosphere for students.

Striking a Balance in Math Education

This balance blends computational fluency with conceptual understanding and strategic competence. Educators now recognize that a blend of these priorities serve students best, and that this balance leads to mathematical proficiency.

Considerable debate has emerged regarding the nature of effective mathematics instruction. This debate has been inspired in large part by the relatively low and stagnating performance of American adolescents, compared to their international peers, on mathematics assessments (e.g., OECD, 2010). Dubbed by some education commentators as the Math Wars, divergent opinions exist on the ideal composition of math instruction to serve students best, raise U.S. math achievement levels, and end stagnating performance.

This debate over the nature of effective math instruction has led to a swinging of the pendulum phenomenon: failure to show gains through one methodology or approach leads to criticism of this method and calls for a dramatic shift in methodology. Like debates surrounding reading instruction, however, growing sentiment has emerged within the math-reform movement that strikes a balance among different instructional approaches. This balance blends computational fluency with conceptual understanding and strategic competence. Educators now recognize that a blend of these approaches serve students best, and that this balance leads to mathematical proficiency.

The *Academy of MATH* is designed with this balance in mind. The program combines conceptual understanding, computational fluency, and strategic competence. It is important to recognize that each of these essential components is not discrete or an individual skill, nor do they compete for instructional attention. Rather, these components are highly interwoven and develop interdependently (Kilpatrick, Swafford, & Findell, 2001).

Conceptual Understanding

Conceptual understanding is the comprehension of mathematical concepts, operations, and relations; it is a deep understanding of how math works. Concepts such as the base-10 number system and the distributivity of multiplication over addition are essential for students to understand. These types of foundational concepts form the backbone of mathematical procedures. Conceptual understanding allows students to build new knowledge as they make connections with previously learned knowledge. This method is far more beneficial to students than simple memorization of facts and procedures. Conceptual understanding promotes retention and fosters the development of fluency (Kilpatrick et al., 2001).

One of the key aspects of conceptual understanding is familiarity with, and knowledge of, the unique language of mathematics. For many students, the classroom is the only place where they are exposed to mathematical language. Mathematics instruction, then, must include sufficient work with vocabulary. Students who are unfamiliar with the language of mathematics, and do not know the meaning behind such terms, will find it extremely difficult to complete mathematical tasks. Instruction that includes the development of conceptual understanding, through directly teaching mathematical language and meaning, provides students with one of the key ingredients of success.

The *Academy of MATH* develops conceptual understanding through the use of explanatory, animated tutorials and multiple-choice questions that focus on the concepts and vocabulary of mathematics. These tutorials introduce students to the subject-area concepts they are about to practice at a particular level in the program.

Typically, the tutorials cover information that has been introduced in the classroom, so the tutorials function as a way to reinforce students' developing conceptual knowledge. These tutorials include essential language, graphical representations that support written explanations, and several examples to emphasize understanding.

Once students have familiarized themselves with the concepts, they begin practicing with questions simply known as Terms. The Terms questions are multiple-choice questions that are designed to help students formalize their understanding of mathematical concepts and math vocabulary. The questions do not require carrying out operations. Instead, students are able to focus on the concepts and vocabulary first before they apply their understanding.

Computational Fluency

Computational fluency is the ability to perform mathematical operations and procedures both accurately and efficiently. It is critically important for students to be able to carry out basic calculations with whole numbers, as well as to be adept at adding, subtracting, multiplying, and dividing multi-digit numbers, both mentally and with paper and pencil (Kilpatrick et al., 2001). The ability of a student to quickly retrieve basic math facts from memory is crucial for that student's success in mathematics. Students that do not possess an adequate level of computational fluency will devote much of their attentional resources to the task of basic computation at the expense of developing a deep understanding of more complex mathematical ideas (Gersten et al., 2009). Without computational fluency, students will likely fail to see important connections between concepts or relationships among operations.

Computational fluency can be developed through methodical, well-timed practice using different mathematical operations. It is important, however, that students practice operations with conceptual understanding. Practice without understanding is virtually meaningless—procedures remain disconnected from other mathematical knowledge. Computational fluency with conceptual understanding promotes the development of accurate and efficient procedures that are unlikely to be forgotten or confused by presenting questions that require students to perform straightforward mathematical procedures such as adding, subtracting, multiplying, and dividing. Once students progress through the Terms questions within the subject area at a particular level, they should have the conceptual understanding necessary to apply this knowledge as they perform calculations.

Within each subject area at a particular level, students develop computational fluency by practicing with questions that require them to complete a calculation and enter an answer. Students are encouraged to use mental strategies when possible, but may find that using a pencil and paper to figure out the problem is helpful—at least until a sufficient level of fluency is achieved. For complex operations, calculators may be appropriate, but this should be left to the teacher's discretion.

Operations questions are presented for a limited time, which forces students to complete a calculation in a timely and efficient manner. Once students successfully complete the collection of Operations problems within the subject area at a particular level, they have achieved a level of computation fluency and conceptual understanding that allows them to progress to more complex problems designed to develop strategic competence.

Strategic Competence

Strategic competence is the ability to interpret and formulate mathematical problems, along with the ability to represent and solve them. It also requires conceptual understanding in order to evaluate the nature of the problem, as well as computational fluency to solve the problem accurately and efficiently. With strategic competence students apply their mathematical knowledge in order to select the most appropriate procedures when faced with a mathematical problem. In a classroom environment, students often have the context necessary to help them decide how to approach a problem. Outside the classroom, however, students often face situations that require them to interpret the nature of the

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problem, determine what information is needed, formulate the problem, select the appropriate strategy, and solve the problem. Students that do not possess adequate strategic competence often do not know how to approach a mathematical problem; they have trouble interpreting the nature of the problem and do not know what strategy or strategies are appropriate to solve the problem. Rather than approaching a problem strategically and with understanding, students without strategic competence will often grab numbers from the problem and perform a calculation using a best-guess strategy.

Students, therefore, must have a bank of strategies from which to choose, along with an understanding of what strategy to apply when approaching a problem. Strategic competence can be developed though frequent exposure to mathematical problems that reflect real-world situations. Mathematical problems that require students to interpret a question, distinguish required from irrelevant information, represent the problem mathematically, and then solve the problem encourage development of strategic competence. Solving mathematical problems proficiently requires a combination of conceptual understanding, computational fluency, and strategic competence.

The *Academy of MATH* encourages the development of strategic competence by using word problems inspired by real-world situations. Once students have gained a conceptual understanding of a subject area at a particular level, and they have demonstrated computational fluency within the subject area, they are then presented with a collection of word problems. The word problems require students to read and interpret a question, determine the necessary information, formulate the problem, and then solve the problem by entering a solution.

As with Terms and Operations, the Problems questions are presented for a limited time, encouraging students to complete the task in a timely manner. If students fail to answer correctly, instructional feedback provides students with a step-by-step explanation of how to solve the problem. The instructional feedback gives students an opportunity to see how to apply the appropriate strategy to the mathematical situation. Students who take advantage of this feedback build the familiarity necessary to apply and solve mathematical problems on their own quickly and accurately.

The *Academy of MATH* is designed to foster mathematical proficiency using a staged approach. Students are first introduced to the essential concepts and language of a specific mathematical subject area at the Tutorial stage of the program. Students then formalize their conceptual understanding as they practice at the Terms stage. Once they have demonstrated sufficient conceptual understanding, students progress to the Operations stage, where they continue to build understanding as they practice carrying out operations. Students develop computational fluency at the Operations stage. After demonstrating understanding and fluency, students are ready to apply this knowledge as they begin to develop strategic competence in interpreting, formulating, and solving word problems, this is the Problems stage.

Research Efficacy Study at Westwood Elementary School

The *Academy of MATH* has been proven time and time again to raise the math achievement of struggling students. One efficacy research study, conducted at Westwood School, Manchester, Tennessee in 2012, demonstrated that students, who were at risk of academic failure, achieved significant mathematical gains by using the *Academy of MATH*.

Design The design of the study was a randomized control trial (RCT) in which standardized and proprietary tests of mathematical ability were used:

- STAR Math Assessment (STAR)
- Discovery Education Assessment Math (DEAM)
- Diagnostic Online Math Assessment (DOMA)
- *Academy of MATH* Placement Test (AoM PT)

The STAR and DEAM are both standardized tests of general mathematical ability. The

DOMA is a test of students' abilities in several mathematics domains. This study focused on two DOMA domains, Numbers & Operations and Measurement. The AoM PT is a measure of mathematical ability, included in the *Academy of MATH* program.

This study met all the requirements of the What Works Clearinghouse. The study also met the U.S. Department of Education's requirements to present strong evidence of the efficacy of an intervention.

Methodology All students in grades 2–4 were pre-tested with the STAR Math Assessment (grade 2) or the Discovery Education Assessment Math (grades 3 and 4). Students who scored in the bottom 30th percentile on STAR or at the Basic/Below Basic Proficiency levels on DEAM were randomly assigned to the treatment or control group.

Students in the treatment group were 'pulled out' from class to train in the *Academy of MATH* three times a week for 30 minutes per session over 18 weeks. In contrast, students in the control group received 'business-as-usual' classroom instruction during that time.

Results Students in the treatment group achieved significantly ($p < .05$) greater gains than students in the control group on the *Academy of MATH* Placement Test (Figure 1). Students who trained in the *Academy of MATH* also made significantly (all $p < .05$) greater gains than control students on the DOMA domains examined (Figure 2). *Academy of MATH* students achieved nearly double the GLE (Grade Level Equivalent) gains than the randomly assigned control group.

Conclusion The study proves that students at risk of academic failure who train in the *Academy of MATH* are able to achieve significantly greater mathematical gains. To obtain a full report of this Westwood study and other *Academy of MATH* studies, visit epsbooks.com/research/studies/.

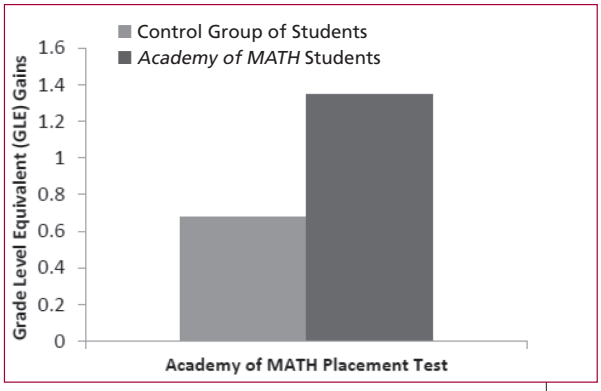

Figure 1

Study findings: *Academy of MATH* students scored more that 2x GLEs than the control group.

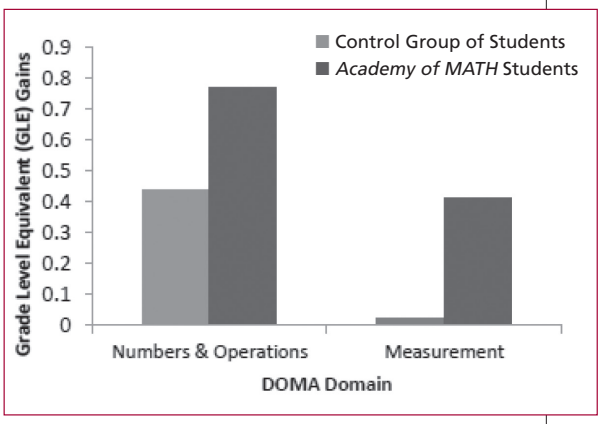

Figure 2

Study findings: *Academy of MATH* students achieved nearly double the GLE (Grade Level Equivalent) gains than the randomly assigned control group.

Conclusion

Like never before, underdeveloped math skills serve as a formidable barrier to participation in today's technologically rich society. Educators all over the world struggle with how best to help their students meet the real-world requirements of math knowledge used in daily life and in their future academic and economic pursuits. The research-based *Academy of MATH* program is proven to be effective in helping students acquire the fundamental math skills they need to achieve success in school and in their future careers.

A powerful instructional methodology is incorporated into the *Academy of MATH*. A unique blend of task analysis, a "practice-makes-proficient" philosophy, and a creative use of motivational principles with mastery learning ensures that students remain engaged and focused on learning math skills and gaining essential math knowledge. Additionally, the program flow is designed to develop

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"Promoting a culture of high expectations for all students is a fundamental goal of the Common Core State Standards..." (Common Core State Standards)

mathematical proficiency by addressing the major components of effective mathematics instruction. Through the sequential delivery of tutorials and practice with mathematical terms, operations, and word problems, students are able to develop conceptual understanding, computational fluency, and strategic competence—all essential elements to mathematical proficiency.

The Common Core State Standards (2010), which have been adopted by a vast majority of states, have been designed to ensure that at every grade level, students learn what they need in order to become college and career ready by the end of grade 12. The National Governors Association Center for Best Practices and the Council of Chief State School Officers of the Common Core State Standards Initiative discuss the common standards' application to students with disabilities, and ensure that, "*Promoting a culture of high expectations for all students is a fundamental goal of the Common Core State Standards. In order to participate with success in the general curriculum, students with disabilities, as appropriate, may be provided additional supports and services, such as:...instructional accommodations—changes in materials or procedures—which do not change the standards but allow students to learn within the framework of the Common Core.*" The *Academy of MATH* lays the groundwork for math success by focusing on the basic foundational mathematics concepts that all students need, and presents those concepts as the Common Core State Standards call for—in a way that allows students to make connections from simple skills to related complex skills within a topic strand, without content gaps at they progress through the program's levels.

Educators are committed to improving the math skills, knowledge, and general math literacy of their students. The *Academy of MATH* is a powerful, proven program designed to help teachers fulfill their commitment, and prepare students for success in school and beyond.

For more information about this and other research-based materials from EPS Literacy and Intervention, visit epsbooks.com or call 800.225.5750.

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