Academy of MATH

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Developing Mathematical Proficiency with AutoSkill Academy of MATH

AutoSkill®
A helping hand for literacy

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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 be literate. This reality is not only true of the skills necessary to navigate text, but it is also true of mathematics. Like never before, a definition of literacy must include the ability to think and reason mathematically, as well as the ability to read. Given the current social and technological environment, weak mathematical knowledge and understanding has an unprecedented ability to limit success in life.

AutoSkill® International Inc., a literacy company dedicated to improving essential life skills for struggling students of all ages, recognizes the importance of developing mathematical knowledge. It seems natural then for a company that, for nearly two decades, has improved the reading skills of emergent and struggling readers to expand its program offering to include mathematics-training software.

The Academy of MATH® is a research-based software program that incorporates much of the same methodology and educational principles employed in the AutoSkill Academy of READING® program. The new software 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 Academy of MATH develops mathematical proficiency by focusing on conceptual understanding, computational fluency and strategic competence across ten mathematical subject areas.

The AutoSkill 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.

AutoSkill has a long history of helping students acquire complex skills. The AutoSkill Academy of READING, for example, breaks down reading into manageable component skills, training students to a level of proficiency and moving them forward, celebrating each incremental step along a developmental continuum. This instructional approach has proven to be effective in teaching struggling readers the component skills necessary for rapid and fluent decoding of text. By learning these skills to a high level of proficiency, students are able to devote the bulk of their cognitive resources to comprehending text.

AutoSkill has incorporated this instructional methodology into the Academy of MATH. This instructional methodology 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 AutoSkill programs 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 requires the coordination of a variety of cognitive abilities; it is essential that the skill is broken down into its component parts, with each part representing a manageable chunk to be learned–successfully. (Vail, 1987, 1994). AutoSkill has long recognized the immense value of this approach to teach complex skills. In the Academy of READING program, the process of learning to read is broken down into manageable skills and trained along a developmental sequence.

Learning math is a complex skill hierarchical in nature. In other words, essential foundation skills must be laid first in order to build high-order skills. As such, the same task-analytic approach employed in the Academy of READING is appropriate for math instruction (Miller & Mercer, 1997). In the Academy of MATH, component skills of mathematics have been broken down and individually addressed, with students trained along a development 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 (Miles & Forcht, 1995). 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 computing with whole numbers.

Proficiency Through Practice

Another important feature of AutoSkill programs is incorporation of a "practice-makes-proficient" philosophy. Educational research on both reading and math continually indicate that structured practice leads to development of accurate and fluent skills (Chall, 1983; Garnett, 1992; Kulak, 1993; Samuels, 1979). Indeed, instructional programs that do not provide sufficient opportunities for students to practice skills are unlikely to produce desired results (Wilson & Sindelar, 1991). Training exercises that repeatedly expose students to the sounds, letters and words of the English language ensure these students develop decoding proficiency. The Academy of MATH incorporates this "practice-makes- proficient" philosophy, ensuring students get 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. The same skills are reintroduced in subsequent graded books at higher skill levels. Basal instruction, using this spiraling curriculum approach, is supposed to add depth to the math topics taught, but in reality the result seems to be superficial coverage of many different skills. Skill mastery is unlikely with this method, because new skills are introduced too quickly in an attempt to "get through the book". Primary concerns regarding basal programs are a lack of adequate practice and review, inadequate sequencing of problems, and an absence of strategic teaching and step-by-step procedures for teaching problem solving (Wilson & Sindelar, 1992). In fact, research has demonstrated that the basal approach to teaching mathematics is particularly detrimental to students who have learning difficulties (Engelmann, Carnine, & Steely, 1991; Silbert & Carnine, 1990; Woodward, 1991). 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 who are moved through a curriculum without understanding foundation skills will continue to experience failure (Miller & Mercer, 1997).

The AutoSkill 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 rate; no student is left behind, no student is held back to allow classmates to catch up.

Principles of Motivation

Another common attribute of AutoSkill programs is the extensive use of motivational principles. AutoSkill has long recognized the value of motivation when it comes to complex skill development and has worked diligently to incorporate several motivational principles into its reading and math software programs. In the Academy of READING, 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 same can be said of the Academy of MATH.

The value of motivation when learning challenging skills cannot be underestimated; this is certainly true of mathematics. Compelling research exists, however, that many students in North America lack sufficient levels of motivation to allow them to succeed at math. National assessment data from the 1980s (Carpenter, Corbitt, Kepner, Lindquist, & Reys, 1981; Dossey, Mullis, Lindquist, & Chambers, 1988) indicate that American children tend to enjoy mathematics in the primary grades, but their level of enjoyment tends to fall dramatically when they progress into and through high school. In addition, although students feel that mathematics is important, the number of students who want to take more mathematics in school is declining steadily (Dossey, et al., 1988). These statistics seem alarming when coupled with the fact that children do not possess the mathematical knowledge that they need to function smoothly in today's increasingly technological society. It is important, then, 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. Brophy (1998) 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 believed to be effective in building struggling students' confidence, and developing intrinsic motivation and a willingness to take the risks necessary to reach challenging goals (Grabe, 1985). Other researchers agree. Stipek, et al., explains 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 and show to their friends. 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 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.

The Reading and Math Connection

All educational stakeholders are dedicated to improving the knowledge and abilities of students. Every parent wants their child to succeed, every teacher wants their students to learn. Principals, superintendents and policy makers at the state and federal level want all students to receive high-quality education to ensure the preservation of a productive society. Without question, the foundational skills upon which success in school and beyond are based pertain to both reading and math. This is not a case of one or the other. Like never before, well-developed skills in both reading and math are essential to success in life.

A survey of recent policy initiatives and research recommendations reveals a significant focus on reading. For example, the recently reauthorized U.S. Elementary and Secondary Education Act, known as No Child Left Behind (2002), described its Reading First program as the academic cornerstone of the entire act. Despite this focus on reading, the act points out that mathematics performance in the United States is unacceptably stagnant. This stagnation is not only shortchanging students' futures, but is also jeopardizing American prosperity and national security.

Educators across North America have responded to policy initiatives and research recommendations by selecting and implementing high-quality, research-based reading programs into their schools in an effort to ensure that no child is left behind. Many of these educators have selected the Academy of READING software program published by AutoSkill as their tool of choice for helping students struggling to learn to read. An overwhelming number of students have been rewarded by this choice. But while these students have improved their reading skills, many continue to demonstrate difficulty in mathematics due to underdeveloped mathematical proficiency.

On the surface, learning to read and learning mathematics are fundamentally different. At a deeper level, however, a strong, albeit largely underappreciated, connection between these skills exists. While much remains to be learned about this connection, research literature is beginning to uncover what appears to be a significant correlation between the challenges students face when acquiring both reading and math skills.

Research indicates that many students who experience difficulty learning to read also experience difficulties learning math. Some estimates suggest that more than half of the children with reading disabilities also have difficulties learning basic arithmetic. Conversely, children diagnosed with math disabilities have difficulties learning how to read (Geary, 2002). Other research suggests that the correlation of reading and math difficulties is much higher. In his analysis of first-year high-school students taking the Ohio Ninth Grade Proficiency Test of Mathematics in the fall of 1991, 1992, and 1993, Tack (1995) discovered that 69 percent of all students either failed both math and reading or passed both math and reading.

The correlation of reading and math difficulties has led several researchers to hypothesize about the connection. In a study by Light and DeFries (1995), the incidence of co-morbid reading-based learning disabilities and mathematical learning disabilities suggests that reading and math deficits may be due, at least in part, to genetic influences. Other research has made a more precise connection, suggesting that many children who show phonologically-based reading disabilities exhibit difficulties in arithmetic retrieval as well (Gersten & Chard, 1999).

Geary (2002) suggests that making letter-sound correspondences and retrieving words from memory employ the same cognitive function as mathematical-fact retrieval. Students who experience difficulty with one task will very likely have difficulty with the other.

Geary's hypothesis is in line with the work of Davis, Pearn, Price and Smith (1997). These researchers suggest that there is a common unitizing feature in the brain that deals with both arithmetic and phonological units. That is to say, children experiencing difficulty processing phonological units are also likely to have difficulty counting or manipulating composite numerical units.

This collection of research findings suggests that students with reading disabilities, or students demonstrating poor reading ability, likely experience similar difficulties in acquiring mathematical knowledge. Even if these students are not experiencing difficulty with math now, research indicates that they will eventually.

Given the likelihood that students struggling with reading will also struggle with math, it seems reasonable to suggest that students who are working with supplementary reading intervention programs will benefit from working with a supplementary mathematics intervention program — a program designed with these students in mind; a program that incorporates key learning principles in an instructional methodology sensitive to the needs of struggling students; a program built upon a proven track record of reversing the downward spiral of academic failure; a program such as the AutoSkill Academy of MATH.

Striking a Balance in Math Education

Considerable debate has emerged recently 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. Dubbed by some education commentators as the Math Wars, divergent opinions exist on the ideal composition of math instruction to serve students best, raise American math 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, a growing methodology 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 methodological approaches and instructional foci serve students best, and that this balance leads to mathematical proficiency.

The AutoSkill Academy of MATH is designed with this balance in mind. The program is a blend of conceptual understanding, computational fluency and strategic competence. It is important to recognize that each of these essential components is not discrete or individual skills, nor do they compete for instructional attention. Rather, these components are highly interwoven and develop interdependently (Kilpatrick, et al., 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 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 the 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 these 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 tutorials and multiple-choice questions that focus on the concepts and unique language 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 concepts include essential language, and 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 the language that surrounds them. The questions do not require carrying-out operations. Instead, students are able to focus on the concepts and language 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). Students that do not possess an adequate level of computational fluency will devote much of their attentional resources to these tasks at the expense of developing a deep understanding of mathematical ideas. Without computational fluency, students will likely fail to see important connections between concepts or relationships among operations.

Computational fluency can be developed though 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.

The Academy of MATH develops computational fluency 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 and 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 a 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. Strategic competence requires conceptual understanding in order to evaluate the nature of the problem, as well as computational fluency to solve the problem accurately and efficiently. Strategic competence also requires students to apply their mathematical knowledge in order to correctly select the most appropriate procedures when faced with a mathematical problem. In a controlled 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 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 well-stocked 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.

Conclusion

At AutoSkill, helping students succeed is our business. Like the educators that use our programs, we are dedicated to improving the educational experience of students who are having difficulty acquiring fundamental skills—particularly in the areas of reading and math. AutoSkill recognizes the importance of these skills for students to become active and productive participants in today's technologically rich society. Like never before, underdeveloped reading and math skills serve as a formidable barrier to such participation.

For almost two decades, AutoSkill has been helping students develop reading skills through the highly effective Academy of READING program. The powerful instructional methodology employed in this reading program has been incorporated into the AutoSkill Academy of MATH. A unique blend of task analysis, a "practice-makes-proficient" philosophy, and a creative use of motivational principles ensures that the same successes enjoyed by Academy of READING users will be enjoyed by Academy of MATH users as well.

Coupled with the AutoSkill instructional methodology is an instructional program flow designed to develop mathematical proficiency by addressing the major components of effective mathematics instruction. Through the sequential delivery of tutorials, terms, operations and problems, students are able to develop conceptual understanding, computational fluency and strategic competence—all essential elements to mathematical proficiency.

Educators across North America are committed to improving the skills, knowledge and understanding of their students. The AutoSkill Academy of MATH program is a powerful, research-based tool designed to help teachers fulfill their commitment.

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About AutoSkill

AutoSkill International Inc. delivers highly effective and scalable reading and math intervention solutions to help struggling elementary, middle and high school students develop fluency in the foundation skills of reading and math. AutoSkill products use a research-based approach that is proven to generate significant and sustainable gains for at-risk students of all ages and abilities. The company's award-winning software provides an individualized and engaging experience for students, and comprehensive set of monitoring, management and reporting tools for teachers and administrators. AutoSkill deploys its reading and math intervention solutions across schools and districts in North America and Europe.

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