Imagine Math Facts Research Principles

"To prepare students for Algebra, [math] curriculum must simultaneously develop conceptual understanding, computational fluency, and problem solving skills. Debates regarding the relative importance of these aspects of mathematical knowledge are misguided."

National Mathematics Advisory Panel (2008)

Introduction

Automatic recall of basic math facts is foundational for later mathematics education. Indeed, students who are fluent in math facts are far more likely to succeed in learning more complex math concepts (Crawford, 2003). Unfortunately, many students (and even adults) across the nation still struggle with these core skills. In fact, the same 2008 National Mathematics Advisory Panel quoted above concedes that "few curricula in the United States provide sufficient practice to ensure fast and efficient solving of basic fact combinations and execution of the standard algorithms."

Both federal and state standards uniformly require that teachers emphasize mastery and automaticity of math facts. For example:

- "By the end of Grade 3, know from memory all products of two one-digit numbers." (Common Core Standard 3.OA.C.7)
- "By the end of Grad 3, recall facts to multiply up to 10 by 10 with automaticity." (Texas Essential Knowledge and Skills for Mathematics A.111.5.B.4F)

As a potential tool for improving computational fluency, the 2008 National Mathematics Advisory Panel recommends computer assisted instruction for developing students' automaticity with the intent of freeing working memory and thereby redirecting attention to the more complicated aspects of math problems. In response to this recommendation, Imagine Math Facts (IMF) stands as the prime option in supplemental educational tools designed to improve math fluency. As an interactive, immersive, and research-based math tool, IMF will substantially improve math fact fluency and automaticity in children of all educational backgrounds. The remainder of this document discusses, in detail, the research-based principles that IMF educational software is built upon and why the application of these principles will improve learning in mathematics.

Fact Fluency

"Students who respond rapidly and accurately tend to score higher on achievement tests that measure higher-level skill development and have lower levels of math anxiety than do students who respond less so."

Poncy, Skinner, and O'Mara (2006)

Success in Fluency

In the first years of elementary education, students are instructed in basic strategies to count and perform simple mathematical calculations using fingers, dots, or other tactile methods (Poncy, 2006). However, such strategies are not efficient nor conducive to rapid, automatic retrieval of math facts necessary for success in later education. Indeed, if better strategies are not eventually learned, a student could experience stagnation in learning mathematics. IMF software aims to ensure all students achieve fact and computational fluency regardless of skill level at program entry. Fact and computational fluency is imperative for later academic success (Woodward, 2006).

Focused Practice

Achieving math fluency necessarily requires multiple opportunities for practice with increasing levels of difficulty (Burns et al., 2015). IMF curriculum is designed so that every student will progress through multiple stages of fact mastery. In beginning stages, each fact is presented several times with lenient response windows. However, as a student moves through subsequent stages, practiced math facts are mingled with distractors and response windows are shortened to emphasize automaticity in fact retrieval. In this format, students must exercise diligence in retaining practiced facts. Each new round of practice is more difficult and requires more automatized processing.

Intensive Curriculum

A study by Hamann & Ashcraft in 1986 revealed a skew in traditional mathematics textbooks towards the presentation of smaller and/or easier math problems such as 2 x 3 or 3 x 3. This is likely due to the fact that most math curricula teach in order of smaller to larger numbers. With this in mind, IMF curriculum is designed to be more intensive by not biasing the order of fact presentation. The learner is intentionally exposed to math facts of varying difficulty and size (such as 9 x 8) throughout the program with the intent of pushing him/her towards mastery of all facts at a similar level.

Skill Mastery

"Competence in a domain requires knowledge of both concepts and procedures. The relations between conceptual and procedural knowledge are bidirectional. It is important that both types of knowledge are inculcated in the classroom"

Rittle-Johnson, Siegler, and Alibali (2001)

Conceptual Understanding

Automatic, free recall of math facts is generally considered an indication of math fluency. However, conceptual understanding of how math facts are computed, particularly for larger or more difficult number combinations, is also necessary for foundational learning (Rittle-Johnson, Siegler, and Alibali, 2001). In this vein, IMF ensures conceptual understanding of math facts by breaking down more difficult problems into their smaller components. For example, a student who is presented 4 x 6 for the first time will initially obtain the solution by computing 1 x 6, 2 x 6, and 3 x 6 and then derive the answer to 4 x 6. Once a correct response is received the following presentations of 4 x 6 will rely more on recall, thus motivating the student to transition to automaticity and become more fluent.

Strategic Recall

Research in cognitive and educational psychology has demonstrated that multiple, spaced presentations of a stimulus is key for enduring memory (Squire, Davies, and Bryant, 2004). Further, delayed recall of learned facts promotes deeper encoding of important memories that the brain will deliberately maintain for future retrieval (Godbole, Delaney, and Verkoeijen, 2014). Relying on this research, IMF curriculum is designed to enhance long-term recall of learned math facts. This is accomplished by employing what is called the spacing effect (Delaney, Verkoeijen, and Spirgel, 2010). Through multiple presentations and delayed recall of each learned fact, depth of learning is enhanced.

Immediate Feedback

As students progress through IMF educational games, they receive constant and immediate feedback about their performance and progress. Both visual and auditory feedback accompanies every math problem. A correct answer is followed by a physical cheer from the primary game character and an auditory tone that increases in pitch with each successive correct answer. Incorrect answers result in no action from the primary game character and no auditory tone. In this way the learner is encouraged with every correct answer but not discouraged with every incorrect answer.

Differentiated Instruction

"Because computer adaptive testing measures involve large item banks and are carefully calibrated, the measures quickly and efficiently indicate where a student's ability falls across a continuum of achievement."

Shapiro, Dennis, and Fu (2015)

Adaptive Placement Testing

Based on the principles of item response theory and computer-adaptive testing (Shapiro, 2015), differentiated instruction begins immediately in IMF with a quick pre-test that assesses prior math skill and competency. Based on the results of the pre-test, learning paths and instruction time are adjusted so that students spend more time on material appropriate for their individual skill level. In this way, no two students experience IMF in the same way. No time is wasted in covering topics already mastered nor will students drown under overly challenging material.

Differentiated Instruction

Following the initial pre-test, students receive instruction unique to their specific needs and adapted to their performance level. Due to variations in background knowledge, motivation, and learning strategies, students will inherently progress through lessons at varying speeds with some lessons being more difficult than others. To reduce frustration and enhance productive learning, IMF is designed to adapt to student performance as he/she progresses through the program. For example, a student who completes a lesson with no mistakes and at a speed suggestive of mastery will not be expected to revisit that same lesson. However, if multiple mistakes are made, additional practice and assessment will be provided to ensure concept mastery before moving on to more challenging material.

Progress Monitoring

An important component of IMF adaptive and differentiated instruction is its built-in progress monitoring features. Student performance data for every lesson and for every assessment is used to constantly adjust the presentation of new material with the intent of meeting the student where they can achieve the greatest level of learning. Further, this information can guide a teacher towards choosing the most appropriate supplementary instruction students may require outside of the IMF software.

Immersive Learning

"People acquire new knowledge and complex skills from game play, suggesting gaming could help address one of the nation's most pressing needs - strengthening our system of education and preparing workers for 21st century jobs."

Summit on Educational Games (2006)

Technology in Education

In an effort to improve average scores on state-wide mathematics assessments, many school districts across the United States have looked for supplemental resources to assist in student learning and achievement. Educational technology has since emerged as a means of engaging students at all grade levels in supplementary mathematics education. Current options in educational technology differ in scope, method of delivery, teaching strategy, and even realism. Though meta-analyses have found general advantages for students who used educational technology as mathematics supplements, current research efforts are now focusing on which types of educational technology best correlate with successes in learning.

Attention, Motivation, and Engagement

Not only is IMF an effective mathematics teaching tool, it is an engaging and interactive experience designed in the style of modern video games. In this format, IMF is able to capture and maintain the attention of virtually every enrolled student. Further, the play style of IMF products increases student motivation to progress through the entire program. New worlds, mini-games, and challenges emerge as the learner accomplishes one milestone after another. Increases in attention, motivation, and engagement naturally lead to improved learning outcomes (Kebritchi, Kirumi, and Bai, 2010).

An Immersive Experience

Recent evidence has begun to reveal game realism and/or immersion as a potential moderator in the relationship between game use and academic gains (Jennett et al., 2008). In fact, a study by Vogel et al. (2006) revealed that "as the realism of the program increases, the amount of knowledge gained during the 'teaching time' also increased." The IMF experience is designed to be immersive and places the student in a world of adventure in which progress is only attained through successful mastery of math facts. In this format, students are more engaged and motivated, have more fun, and even learn more (Freitas, 2007).

Teaching Students with Disabilities

"All students with mathematics difficulties require special attention. These students have special educational needs, need extra help, and typically require some type of specific mathematics intervention"

Kroesbergen and Van Luit (2003)

Accessibility

Despite widespread use of computers and electrons among children, significant variation still exists in experience and skill with various electronics (Vatavu, Cramariuc, and Schipor, 2015). This is particularly true for children with learning disabilities or similar challenges. IMF software is designed to accommodate even the most novice of users. Before instruction begins, all IMF users are assessed on typing speed and numeracy skill. Further, a brief tutorial is administered to ensure each student is successful in navigating IMF games. This includes familiarity with character control and the answer-response system. This extra help minimizes accidental errors and guides students through the program making IMF a mathematics instruction tool accessible for all students.

Differentiated Instruction

Often students with disabilities do not receive sufficient instruction on topics in which they struggle the most. Indeed, educators are well aware that no one teaching strategy or curriculum is intended to be one-size-fits-all. With IMF, every student receives differentiated, individualized instruction. If a learning disability has previously been identified, IMF achievement standards can be automatically adjusted to meet the student at their ability level. Further, teachers are granted the ability to manually override core standards to further tailor a student's experience.

Extended Practice

Extra and extended practice opportunities are essential in helping students with learning disabilities achieve outcomes on par with their peers (Kroesbergen and Van Luit, 2003). This in mind, IMF is designed to provide students with as many practice and learning sessions as necessary to achieve skill mastery. If after multiple extra practice rounds a student still struggles, further accommodations are then applied, such as relaxed response windows, which encourage progress but still promote learning. Despite these adjustments, all students are still expected to ultimately achieve mastery of each math fact.

An Effective Solution

"From the findings of this study, video games as a supplementary activity to classroom learning brings significant and positive effects on students' retention and mastery of multiplication tables as compared to students who rely only upon formal classroom instruction."

Abdulla et al., 2012

Demonstrated Efficacy

IMF software has already impacted student learning in multiple countries across the globe. For example, a study conducted by Abdullah et al. (2012) demonstrated the effectiveness of IMF educational games in helping students in Malaysia learn multiplication facts.

In this study, 100 students were randomly divided into two equal and matched groups to compare the impact of using Timez Attack, the multiplication game in IMF, on multiplication fact mastery. One group (50 students) played Timez Attack for 3 months while the other group received the conventional teacher-led training for the same duration of time. A post test administered at the end of the 3-month period was used as an indicator of student learning.

The results of this study revealed a significant advantage for students who used Timez Attack during the 3-month period when compared to students who received conventional teacher-led training. Students who used Timez Attack achieved average post-test scores double that of the non-users group. Further, the authors of the study determined that the achievement of Timez Attack students was not respective of gender or socioeconomic status.

Unlimited Potential

The results of the above study highlight only a single case in which IMF educational software has improved multiplication fact fluency. Indeed, thousands more students are currently benefiting from this research-based product. Through innovative technology and curriculum, IMF is able to deliver high quality math instruction to all types of students.

As a important member of the Imagine Learning family, IMF is always improving and finding new ways to reach students wherever they may be and no matter their current academic level.

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