A Scientific Learning Whitepaper

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Generalization: Making Learning More than a "Classroom Exercise"

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What is Generalization?

As educators, we ask students to do many things, from memorizing multiplication tables, to writing essays, from reciting poetry to conducting scientific experiments. Yet even the most elaborate classroom project is but a means to an end; all of these activities are intended to help students become informed citizens, effective communicators, reflective decision makers, and insightful problem solvers, whatever their future pursuits. Achieving this goal means teaching for generalization, and this focus affects what we teach, how we teach, even when and why we assess.

Generalization (or transfer) of learning is the ability to take skills or concepts learned in one context and apply them to novel problems in different contexts. Many problems are superficially different but structurally similar; generalization requires looking past the superficial differences to perceive the deeper relationships. For example, consider two problems that require an understanding of percentages: answering a percentage problem on a worksheet in a quiet classroom versus mentally calculating the sales tax on a large purchase in a busy store. While these are very similar problems, they are presented and organized differently, in the context of very different social and emotional cues.

Much as we might like to assume that "if we teach it, they will apply it," this view has been debunked by more than a century of research. Studies show that learners often fail to apply known skills and strategies to novel problems, whether the learners in question are rats in mazes, adults solving puzzles, or school children in the classroom (Marini & Genereux, 1995). These findings have spurred further research to identify conditions that foster generalization for various skills.

Student success hinges on the acquisition and generalization of many skills, including cognitive skills and academic skills. Cognitive skills, such as memory, attention, processing and sequencing, provide a foundation that is critical for other kinds of learning, both in and out of school. Educators build on this foundation through academic instruction – teaching students how to read, perform mathematical computations, place current events in historical context, etc. Despite the differences in these skill sets, generalization is crucial for both cognitive and academic skills.

Generalization in Cognitive Skill Development

The question of "does it generalize?" has been particularly controversial in the area of cognitive skill development. Cognitive skills are conceptualized as general-purpose abilities that serve all kinds of learning. Indeed, research has shown that strong cognitive skills predict later academic success (Duncan, et al., 2007; Swanson, Jerman, & Zheng, 2008). Still, some critics have contended that cognitive skill training is too narrow, and too different from academic learning, to help students who are struggling in the classroom.

Recent research in the domain of working-memory skills has added fuel to this controversy. For instance, a 2013 meta-analysis by Melby-Lervag and Hulme found no evidence that working memory training produces sustained benefit in academic skills, such as arithmetic and decoding. In 2009, Holmes, Gathercole, and Dunning reported significant gains in working memory following the use of an adaptive program. However, when the same authors later focused on generalization, they found that student gains did not transfer to improved performance on academic tasks – even for tasks known to place high demands on working memory (Dunning, Holmes & Gathercole, 2013). They concluded that the adaptive program used in their studies was effective at building the targeted working memory skills, but that it neglected to provide the scaffolding and support needed to generalize these skills into academic tasks and other real-life situations.

According to Amso and Scerif, in their 2015 literature review, the area of visual attention training has yielded similar results. Repetitively exercising one cognitive domain may produce near-transfer without far-transfer. In other words, learners may get better at tasks that are very similar to the training task, without generalizing their learning more broadly, or showing improved educational achievement. The authors concluded that the simplest training approaches are not optimal for promoting generalization. Instead, programs should take a more complex approach, strengthening multiple top-down and bottom-up processing systems.

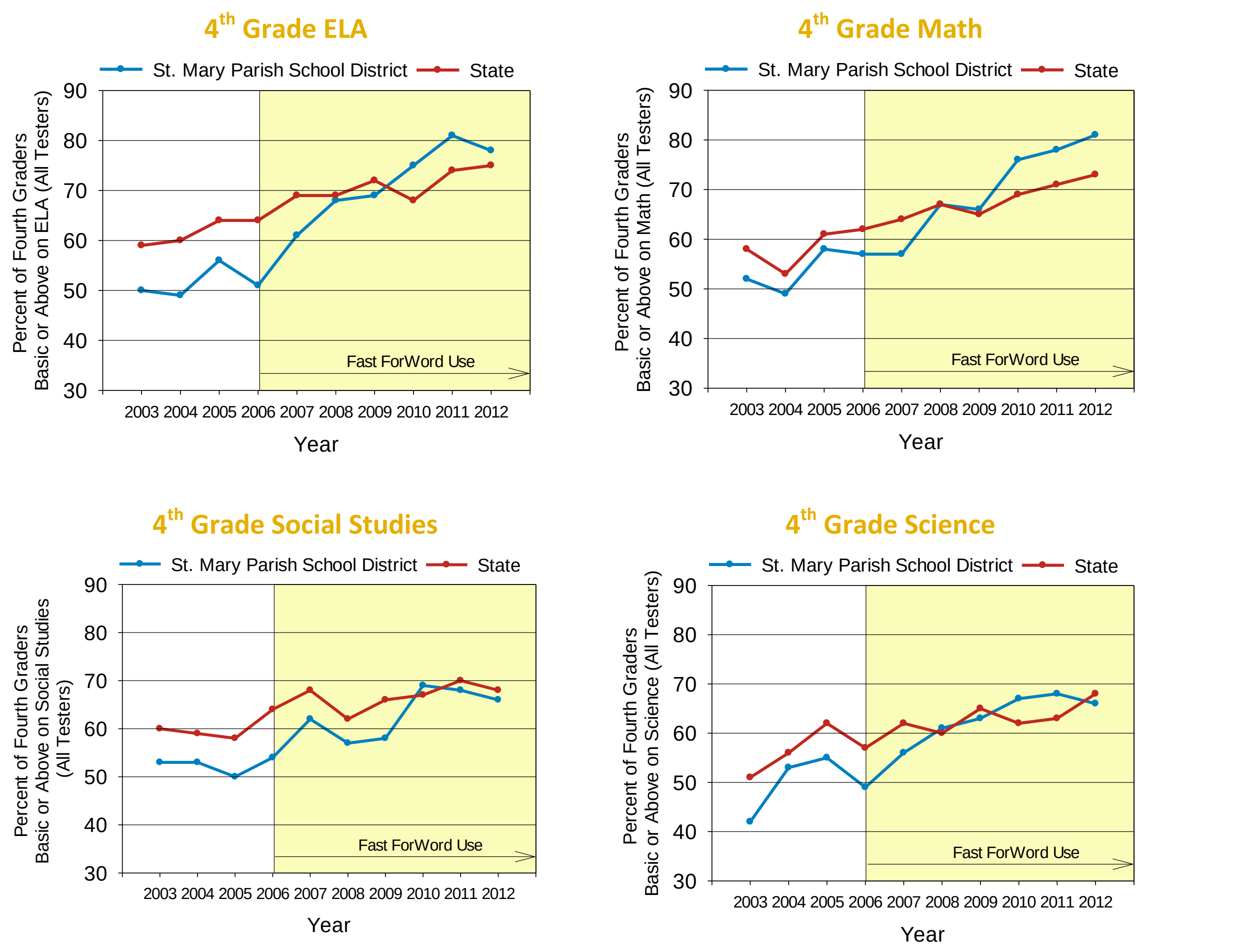
Bridging the Gap

An example of this more complex approach can be seen in the Fast ForWord family of products. Based on decades of research into how students learn, the products build top-down skills, such as working memory and attention, along with bottom-up skills such as perceptual processing. Furthermore, the products build these cognitive skills in the context of language and literacy activities, promoting transfer by bridging the gap between learning isolated skills and applying them in meaningful activities.

Fast ForWord supports generalization through the combined principles of simultaneous development and cross-training. Each Fast ForWord exercise focuses on a specific language or reading task while simultaneously developing underlying cognitive skills such as memory, attention, and processing. Different exercises are combined within a Fast ForWord product to cross-train each skill using different tasks and stimuli. Simultaneous development and cross-training ensures that each product engages multiple components of the highly interconnected networks of brain structures involved in language, reading, and learning.

The design of the Fast ForWord product sequence also supports generalization and the application of cognitive skills to learning academic subjects. In the most typical sequence, a student begins with a product that builds core cognitive and language skills, using tasks that bear little resemblance to familiar academic activities. Subsequent products continue to build on those core cognitive skills, but they increasingly focus on more advanced language and reading skills, using tasks modeled after best practices academic instruction. Because they receive extensive practice in applying their new cognitive skills to authentic reading and language arts activities, Fast ForWord users are well positioned to generalize these skills to the classroom and beyond.

School-based research indicates that students who use the Fast ForWord products are successful at generalizing their cognitive skill gains. For instance, a longitudinal study conducted with the Everett Public Schools (Scientific Learning, 2010) found that students made significant reading achievement gains during the year that they used the Fast ForWord products, and that they continued to make reading gains in subsequent years. Another study, conducted with the St. Mary Parish Schools (Scientific Learning, 2013) evaluated student results across the subject areas of English Language Arts, Math, Science, and Social Studies. After district-wide Fast ForWord adoption, students improved their achievement levels in all four domains, as shown in figures 1-4.



Figures 1-4. Results on the Louisiana Educational Assessment Program (LEAP) for fourth graders in the Saint Mary Parish district, compared to students statewide, for test years 2003-2012. The Fast ForWord products were adopted by district elementary schools between the 2007 and 2009 test years.

Results like these indicate that the Fast ForWord approach builds cognitive skills that generalize, helping students to attain and sustain improved learning trajectories and to get more out of the classroom curriculum, across disciplines.

Generalization in Classroom Instruction

Teaching for generalization doesn't require starting over with entirely new methods of instruction. Established, time-tested approaches can be very successful, when used at the right time for the right material. For example, despite their philosophical differences, both discovery learning and direct instruction can promote generalization when used appropriately. Likewise, well-timed and thoughtfully constructed assessments can be much more than the final resting place for so much classroom learning.

Educators can promote cross-disciplinary thinking by presenting multiple examples, revisiting ideas in different contexts, and assigning projects that cross domain boundaries. The use of multiple examples is especially important for helping students to distinguish the core features of a concept from superficial features linked to a specific context (Gick and Holyoak, 1983). At the same time, building deep, domain-specific knowledge is also critical since it helps students recognize structural similarities between prior learning and new problems encountered in different contexts.

Figuring something out for oneself requires deep and active mental processing, which is one reason why discovery learning approaches can promote generalization. These approaches work well for concepts that can be readily induced from the feedback learners generate through exploration, and they help to prepare learners who can invent novel solutions (McDaniel and Schlager, 1990). Direct instruction approaches can also promote generalization by efficiently helping learners to build deep domain-specific knowledge, and to focus on core concepts.

Direct instruction can also be integrated into a blended approach known as assisted- or enhanced-discovery learning. In one study of this approach, Chen and Klahr (1999) attempted to teach a challenging principle of experimental design to children in grades 2-4, using varied levels of support. They found that only the highest level of support led to effective learning. When they combined discovery learning with leading probe questions and direct instruction, even the youngest students were able to learn the principle, and the oldest students were able to generalize the principle to new conceptual domains. Indeed, a large body of research indicates that the blended approach is superior to either unsupported discovery learning or direct instruction alone (Alfieri, Brooks, Aldrich & Tenenbaum, 2011).

Another approach that successfully blends discovery learning with direct instruction is widely used in Japanese math classes. Students are presented with solved problems and asked to explain why the solutions are correct or incorrect. This task combines the active, analytic thinking of discovery learning with the targeted focus of direct instruction. Research with students in the U.S. found that this method improved the learning of math concepts and markedly improved generalization (Siegler, 2002).

Assessment can also play an important role in teaching for generalization. We know that testing boosts learning by helping students strengthen the retrieval component of memory. There is also a growing body of evidence that testing boosts generalization. Studies show that taking a practice test is more effective as a study strategy than rereading a text or reviewing notes (Carpenter, 2012). Tested students retain what they have learned over longer periods of time, they perform better when faced with new test formats, and they are more likely to make inferences both within and across knowledge domains. Informal testing with feedback can also improve metacognitive awareness – helping students to understand their own thinking and learning, and to recognize when they need to change their learning strategies.

Conclusion

After all the "high stakes" tests have been taken, grades recorded, and diplomas handed out, the real test begins. Have your students built the knowledge, skills, and dispositions that will serve them in their lives and help them become productive members of their communities? The answer to this question hinges on whether your instructional approaches and materials promote generalization.

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