assume they did not also apply other efficient schemas to help discover the new structures. When the children moved the pieces around, their schemas enabled them to repeatedly count pieces and groups, and to interpret groups of equivalent size as better than groups of different sizes (which led them to make four groups of equal size).

4. 5 A Hypothetical OAC (Optimal Adaptability Corridor).

The preceding discussion leads us to believe that the modified illustration in Figure 10 may be helpful for thinking about the kinds of educational experiences that fit the goals of the superintendents discussed at the beginning of this paper. This figure shows a hypothetical optimal adaptability corridor, or OAC, for the development of adaptive expertise. Its function is to help insure that innovation and efficiency develop together. For example, in the preceding studies on teaching psychology and statistics, the most successful combinations included both opportunities for innovation (e.g., inventing statistics to solve problems) and opportunities for learning efficient solutions invented by experts.

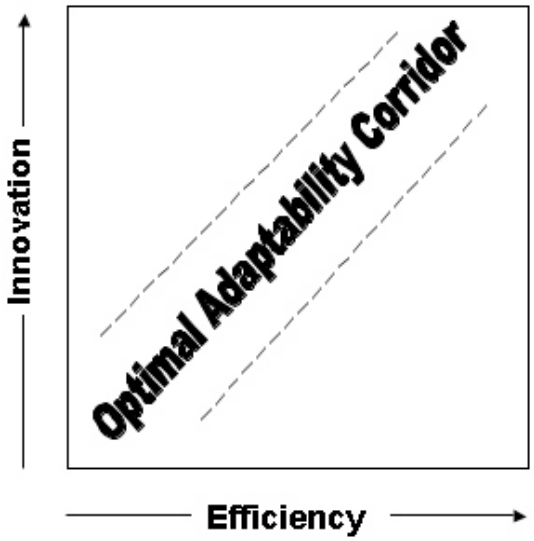

Figure 10: Balancing efficiency and innovation in learning. Is the development of adaptive expertise cultivated by instruction that stays within the Optimal Adaptability Corridor (OAC)?

The presumed outcomes of keeping educational experiences within the OAC involves what Hatano and Inagaki (1986) called "adaptive expertise." Within their base domains, both routine experts (who at the extreme would be trained only along the efficiency dimension) and adaptive experts (whose experiences would tend to fit within the corridor) are highly efficient at solving a number of problems that have become routine for them. However, given a highly novel problem within their domain, or a problem within a new domain, only the adaptive experts can utilize their existing knowledge and practices to learn with the resources at hand. We noted earlier that Wineburg's (1998) studies of historians who were asked to solve problems about areas of history where they were not experts provides an excellent illustration of this kind of performance. Notably, Wineburg used what we call PFL assessments because he provided the historians with resources for new learning. This kind of assessment was necessary to reveal their adaptive expertise.

If we think of the OAC as extending developmentally over a range of ages, young children will typically fall at the low/low end of the vertical and horizontal dimension (we do not, however, assume that young learners are "blank slates" – see NRC,2000). If we assume that both efficiency and innovation are important, the question is how to balance the two. A study by Martin and Schwartz (2004) provides an example of research that looks at different trajectories through the corridor and their effects on transfer. In this study, children learned to manipulate pieces to help solve fraction addition problems over three days. One group of children learned with pie pieces (half pieces in pink, quarter pieces in yellow, and so on). The other group learned with simple tiles of equal size. Both groups received feedback and models of solutions when needed.

Overall the children in each condition learned at the same rate. However, Martin and Schwartz thought the pie pieces might have some detrimental effects for subsequent learning. When looking at pie wedges put together, it is easy to interpret them as part of a whole (e.g., as in a pizza missing one slice). The interpretation of "wholeness" is built into the environment, given people's natural perceptual proclivities. In contrast, when looking at several tiles, it is harder to interpret them as part of a whole. To learn to work with the tiles, children had to innovate new interpretations of the pieces so they were no longer just units; they were also parts of a whole. Thus, the tile students would have a leg-up on the innovation dimension, whereas the pie students would have a leg-up on the efficiency dimension.

To determine whether these different initial experiences had an effect on their learning trajectory at transfer, students in each condition solved problems using new materials at the end of each day. For example, they had to solve problems with beans, which are analogs of tiles. And, they had to solve problems with bars, which are analogs of pies (they come in different lengths colored to indicate whether they are one-fourth, one-half, and so on). The problems the children had to solve were of the same type they had successfully solved earlier in the day when working with the tiles or pies. Thus, the study made sure that the transfer problems were types the students had already learned to solve with their base materials.

Figure 11 schematizes the resulting trajectories through the innovation by efficiency space. For each transfer problem, there were two types of correct performance. One performance was whether children gave the correct verbal answer to a problem. This is an efficient response, because it is the right answer. The other correct

performance occurred when children created a correct physical arrangement of the pieces. This is an innovative response, because the children were adapting the physical environment in new ways to help solve the problem. Children could give an efficient verbal response without arranging the pieces correctly, and they could arrange the pieces correctly without knowing how to interpret them verbally. The figure schematizes the changing proportions of correct innovative and efficient responses over the three days. One may see that the tile students accelerated along the innovation dimension at first and then increased in efficiency. The pie students accelerated along the efficiency dimension at first. Thus, the manipulation of asking the students to learn with tiles or pies affected movement through the space.

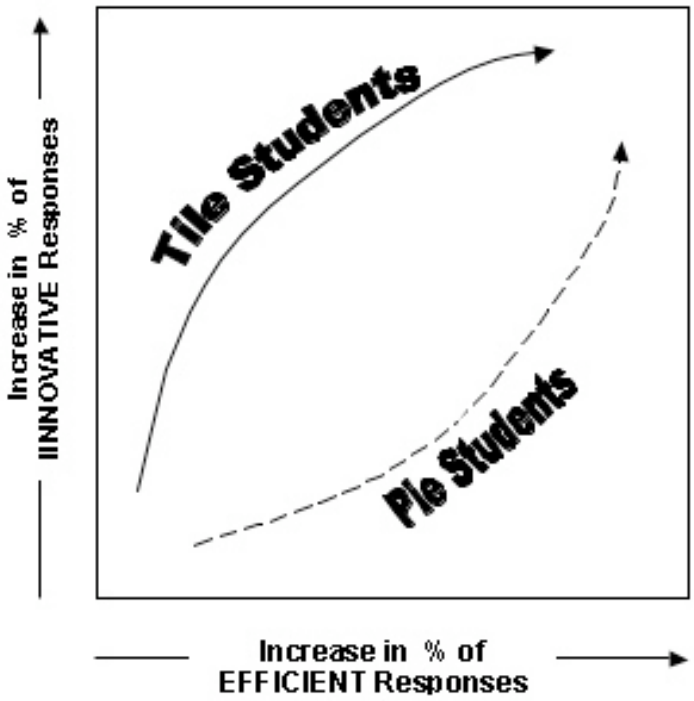

Figure 11. Trajectories of learning at transfer for students who initially learned fraction addition using pie wedges or tile pieces. At transfer, students had to solve fraction problems using new materials (e.g., beans or bars). Correct innovative responses adapted the new materials into useful configurations. Correct efficient responses gave the right verbal answer. Over time, the students who initially learned with tiles exhibited a better ability to adapt the novel materials, showed more stable progress, and ultimately became more efficient than students who initially learned with pies and were more efficient at first (Martin & Schwartz, 2004).

The important finding was that the pie students who exhibited more efficiency at first were actually on a much less stable trajectory. They often got stuck in the space and did not progress, and even when they made progress, they often regressed on the next day. For example, over 50% of the time a pie child reached the upper-right quadrant of "adaptive expertise," he or she regressed on the next day making both incorrect physical arrangements and incorrect verbal answers. In contrast, the tile students demonstrated a very stable trajectory. They rarely got stuck and tended to do better on each successive day. Moreover, they did not regress. For example, when students reached the upper-right quadrant, less than 15% regressed by making an error the next day. Based on this initial study, it appears that early innovation yields better adaptability in the short run and better efficiency in the long run in transfer situations. Needless to say, there is much more research to do on the concept of the OAC.

5. Summary and Future Directions

We began this chapter by describing a common goal among several superintendents. They want graduates from their schools to be in a position to learn and make their own decisions. Having some expertise in the topic of transfer, it was disappointing to us that the transfer literature could not be more helpful in explaining whether this is possible or how to encourage it. The problem is not simply that there is a shortage of experimental research on transfer, or even a shortage of field research that examines transitions from school to work and life. Multiple researchers have looked at the effects of schooling on transfer to everyday situations, often with gloomy results. The problem is that transfer research has not developed a set of constructs or methods suited