Sabbatical Mini-Report #3: Life in the Grey Zone

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Practice. Drill & kill.

We tend to have strong opinions on "how much is enough". I've noticed that math courses require significantly less practice in 2006 than they did in 1996 or 1986. What does the research say about the quantity and quality of practice?

At the highest level of analysis, additional practice produces better learning. Here is a quote from one source (Bruning, 2003, pg 177):

> "The more one practices, the better one gets regardless of initial talent and ability. A second finding is that initial differences attributable to talent and ability decrease over time as a function of practice. A third finding is that the quality, in addition to the quantity, of practice is extremely important."

In other words, enough practice levels the playing field – allowing for equal performance in the course, regardless of pre-existing knowledge. (See Anderson, et al, for more support of this.)

How much practice is enough? Consider this summary of Speelman and Kirsner (2005, pg 129)

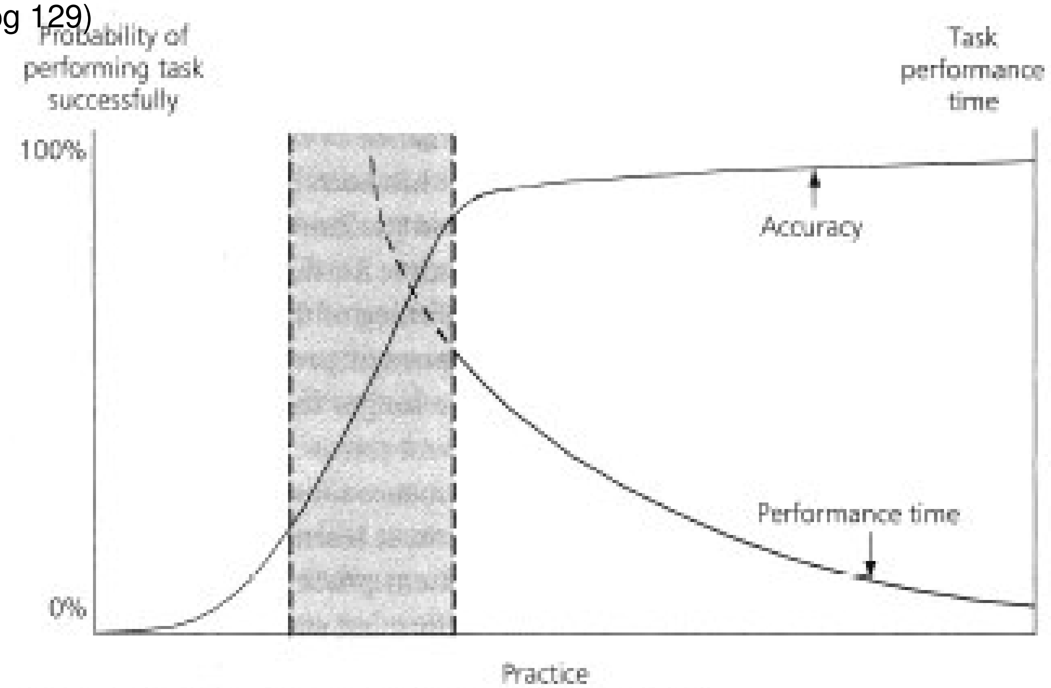

Fig. 4.2 Performance curves underlying skill development.

A given task combines old skills and new skills. If we assume that the student is accurate with the old skills, then there needs to be enough practice to achieve both accuracy with the new skills AND improve performance time. If "old skills" are not accurate, then additional practice would be necessary.

Performance time is initially high, even with accuracy, because the student is recreating the process each time … (1) recalling 'declarative knowledge' ("the book said to do …"), (2) applying analogy to the current problem, and (3) thinking about the next step.

Once accuracy is achieved, performance time can begin dropping – improvements due to several factors. One factor is that the student no longer needs to do the first 2 processes. A second factor is that the 3rd process becomes more 'automatic' – it becomes a 'chunk' to retrieve, not a set of steps to figure out. A third factor is habituation.

Why is performance time important? Two distinct reasons are cited. First, if the student is still referring to declarative knowledge, their mental load is higher – resulting in more mistakes and longer testing times. A second reason is affective … a feeling of competence develops after the accuracy and during the drop in performance time. This feeling of competence is one of the cures for anxiety; math anxious students get less anxious as they experience feelings of self-efficacy. (See Bruning et al, page 126.)

There are also indications that learning is retained better if performance time has decreased; see Anderson (1992) and the discussion of 'automaticity'.

The drop in performance time is a function of the learner and the material involved, which means that there is not an ideal amount of practice for all students. However, improved performance time occurs AFTER accuracy; the achievement of accuracy requires a minimum of two items. (Being correct on the first item does not equate with accuracy.) Improved performance time would then occur (in the best situation) starting with the third problem of a type. Therefore, a good rule might be to provide at least 4 practice problems of each type. (These are often called 'training events" or "trials" in the literature.)

Grey Zone?

In my view, we often limit our quantity of homework to an amount that will get most students only to the grey zone in the graph. Students "have seen it" and "understood it" (sort of); however, accuracy is "just enough" and performance time is not adequate for self-efficacy and retaining material.

Block it … or mix it

The researchers in this field also talk about “blocked” and “unblocked” practice. Blocked practice has a consistent type of problems – all type A problems appear, then all type B problems. There is strong evidence that learning is better with unblocked practice, in which practice is mixed. (See Speelman and Kirsner, pages 75-76.) The results seem to show that mixed (unblocked) practice leads to better retention and better transfer, as learners need to do “identification of type”. This is also supported by memory theory, which suggests that “fast learning” tends to stay in working memory (short term); slower work tends to produce long term memory units. (See O’Reilly pg 153.)

The issue not resolved in the literature is whether all practice should be mixed (unblocked). However, to the extent that students tend to be discouraged, we should start practice with some blocked practice – to build self-efficacy, and then provide mixed practice.

As you might be trying to interpret this material, keep in mind that researchers on learning theory have very strict standards of ‘blocked practice’. All procedures used must be identical; in other words, these problems are **NOT blocked**:

$$4x+3(x-4)=5x$$
$$4x-3(x-4)=5x$$
$$8x-(3x+4)=5x$$
$$9-(3x+4)=5x$$

To these researchers, these are 4 types of problems; this group of problems would be classified as unblocked (mixed). Each involves at least one unique process, no matter how trivial it might seem to us. These differences might involve “decoding” skills, such as knowing how to interpret a subtraction sign preceding a product to distribute. In many cases, it is exactly these decoding skills that enable students to become successful.

You might want to investigate the Kumon program, where practice is heavily emphasized … with the performance criterion being accuracy and speed; see the 2003 reference by Oakley et al for starters. They describe a use of the Kumon program in the Pontiac (MI) public schools. The Oakley 2005 reference describes the results.

A quick summary for skill mastery: If in doubt, add more practice; for important skills, at least 4 repetitions of each combination (type) is a benchmark. Include additional mixed practice whenever possible, probably after building each type. More practice is good; the issue is motivation (see Anderson et al).

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