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ABSTRACT

It is argued that mastery learning is one explanation for the documented differences in mathematics achievement between Japanese and American students. Given its emphasis on mastery at one stage before moving on to the next stage, and the potential accumulated benefits of this approach over time, mastery learning appears to be very similar to what occurs in Japanese classrooms. A meta-analysis of studies of elementary mathematics achievement supports the research findings of H. W. Stevenson and S. Y. Lee (1990). The overlapping confidence intervals of Japanese mathematics performance and mastery learning do not support a positive conclusion that mastery learning caused the differences, but they do indicate that there is a potential relationship. The role of mastery learning in mathematics deserves further exploration. An appendix contains a chart of the studies reviewed. (Contains 3 figures and 18 references.) (SLD)

Why Mastery Matters

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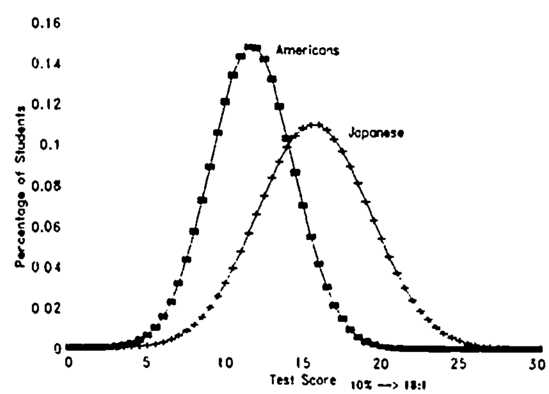
"We have known for some time now," say Stigler and Perry (1990, 328), "that American secondary school students compare poorly on tests of mathematics achievement with students from many other countries, but especially with students from Japan. More recently, Asian-American differences in achievement have been found to exist as early as kindergarten and to be dramatic by the time children reach fifth grade." Using meta-analytic techniques to summarize the results of Stevenson and Lee's (1990, 21) multi-national battery of tests, and collapsing the data across 'operations' and 'problem solving' and across first and fifth grades we see that Japanese students' math achievement has a standardized mean difference (d) of 0.78 better than their American counter-parts, with a 95% confidence interval of 0.70 to 0.90, shown in the graph below. Stigler and Perry go on to say, "Explaining differences as dramatic as these presents a challenge to researchers and also to educators who must grapple with the problem of declining mathematical competence in American society. Where should we look for explanations?"

Japanese Math Superiority



In seeking an explanation, this paper will argue that Mastery Learning is one explanation for Asian-American differences in mathematics achievement. Moreover, the comparison of Mastery Learning with Japanese teaching techniques can show us something important, and hitherto un-investigated, about Mastery Learning.

The seeds of an explanation for Japanese mathematics superiority can be found in a thirteenth century Rinzai Zen monastery, where in seeking enlightenment a monk solves koans. A koan is:

> a succinct paradoxical statement or question used as a meditation discipline for novices.... The effort to 'solve' a <u>koan</u> is intended to exhaust the analytic intellect and the egoistic will, readying the mind to entertain an appropriate response on the intuitive level. Each such exercise constitutes both a communication of some aspect of Zen experience and a test of the novice's competence (Micropaedia 1990, Kapleau 1980).

About this 'exercise' Suzuki (1970, 99) has the following to say:

> Devote yourself to it day and night, whether sitting or lying, whether walking or standing; devote yourselves to its solution during the entire course of the twelve periods. Even when dressing or taking meals, or attending to your natural wants, you have your every thought fixed on the koan. Make resolute efforts to keep it always before your mind.

This pattern of intense focus on a small problem, mastering it, and the use of this sense of mastery as a guide to the tackling of new tasks typifies one influence that Zen has had on a number of Asian arts.

For example, anybody can flail his arms in a street fight and any child can finger paint. To fight or paint well, however, the student must learn the rules of the craft, that is, he must get the rules down to a science. The traditional Japanese student of the martial or painting arts did not begin by engaging in entire fights and slowly perfecting them. Nor did he begin by painting entire landscapes and slowly improve his technique as a whole. Rather, the student began by the tedious mastery of a very small domain, say the forward right-hand punch or the simplest of bamboo leafs. Sogen and Katsujo (1983, 89-90) explain:

> The basis of Oriental calligraphy and painting is the line. Traditionally, students of both disciplines were instructed to spend a minimum of three years concentrating on the brushing of straight lines.

Merely learning the rules of a domain, alas, does not produce mastery. To throw a superior forward right-hand punch or to paint an attractive bamboo leaf, the student had to know when and how to go beyond the rules, how to, so to speak, get the rules down to an art. Unfortunately, the timely breaking of a few rules does not a true master make. The student is considered to have thrown the perfect punch and to have painted the exquisite leaf when he achieves <u>muga</u> [<u>mu</u> = 'not,' <u>ga</u> = 'self']. <u>Muga</u> is "a state of expertness in which there is no break, 'not even the thickness of a hair' between a man's will and his act" (Benedict 1946, 235). The student is considered to have mastery of throwing the forward right-hand punch or painting a bamboo leaf when he has left the rules behind altogether. Or, to stretch the idiom, from getting the rules down to a science, and then getting them down to an art, the student now has them down to a religion, i.e., Zen.

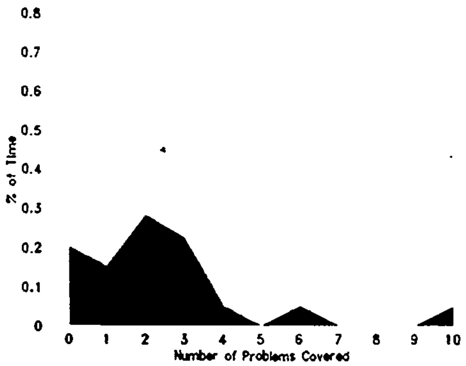
Once the student has reached this stage of mastery in the very small domain of the forward right-hand punch or the single bamboo leaf, he is ready to practice throwing the forward left-hand punch or painting a bamboo stalk. But this time he has an advantage. Having achieved mastery once, the student has a sense of how it feels; this feeling guides him as he tackles new tasks. When throwing the left-hand punch or painting the stalk, he knows what to look for. He knows that he seeks muga and that he can accomplish it. He has gained a taste of excellence. As the eighteenth century Zen painter Shen Tsung-ch'ien explained, "Once this is mastered, the skill so acquired can be freely applied to other objects. ... Without this skill, the more effort is put into it, the more wooden the picture becomes" (Lin 1967, 163).

Returning to the twentieth century, the parallel I wish to draw is between the amount of time the traditional Japanese artist spent mastering the smallest domain of his craft and the amount of time Japanese students spend working on just one or two mathematics problems. After observing American, Chinese, and Japanese mathematics classrooms, Stigler (1988, 29) noted:

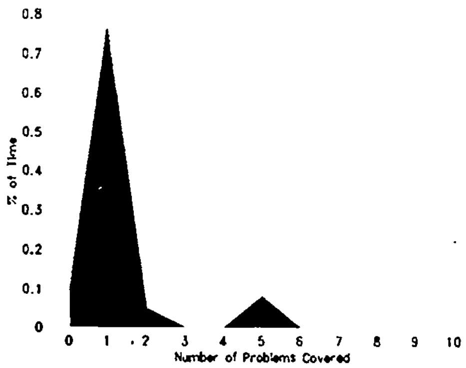
> Only teachers in Japan were ever observed to spend an entire forty-minute lesson on one or two problems. To illustrate this point, we coded the number of mathematical problems covered during all fifth-grade instructional segments with durations of five minutes. The distribution of segments according to number of problems covered is presented

in the figures shown below. While the school in Chicago rushed through as many as ten problems, the Japanese school sought to master only one or two. Herein, I submit, lies one key to explaining Japanese mathematics superiority.

Chicago



Japan



Given its emphasis on mastery at one stage before moving on to the next and the potential accumulated benefits of this over time, Mastery Learning (Carroll 1963, 723; Block 1971 & 1974) appears to be very similar to what occurs in Asian math classrooms, a parallel I am not alone in drawing (Postlethwaite 1988, xix).

To see if Mastery Learning could potentially explain Japanese math superiority, I meta-analyzed all of the studies of elementary mathematics achievement that I could find (see Appendix) to get a weighted mean effect size of 0.78 (95% C.I. of 0.62 to 0.92, N = 769), a result statistically identical with the results of Stevenson and Lee's (1990, 21) findings of d = 0.78, 95% C.I. = 0.70 to 0.90.

The overlapping confidence intervals of Japanese math performance and Mastery Learning do not, of course, allow us to positively conclude that Mastery Learning caused the difference; nor can we conclude that the two are necessarily even related. We can conclude that there is a potential relationship. Mastery Learning, by itself, could potentially explain the difference. Since the confidence intervals do overlap, and since similar effects could be produced by similar causes, we have good statistical reasons to conclude that further investigation is warranted.

If the interpretations offered here of Japanese teaching practices and of Mastery Learning's effects on mathematics achievement are correct, then mastery matters in three ways.

First, if there is an isomorphism between Asian classrooms and Mastery Learning, and if my interpretation of Zen's influence on Asian education is accurate, then one might expect to find that students who had undergone Mastery Learning would have a generalizable 'sense of mastery' that could act 'as a guide to the tackling of new tasks.' This is an aspect of Mastery Learning that has yet to be investigated.

Second, Hedges and Friedman (1993, 102) have suggested that male scientists out-number female scientists to the degree they do, because males out-number females in the upper tails of mathematics achievement distributions. Applying the same type of analysis to American and Japanese mathematics achievement, we see in the first figure above that in the top ten percent of the distribution, Japanese out-perform Americans 18 to one. If we want Americans to be able to compete at an international level in science, then we will have to drastically increase the mathematics performance of what are already our best students. Mastery Learning provides one way to do this.

Third, if it is true that by intense focus on few problems Japanese math students not only become better at math but also develop a heightened and ultimately useful sense of academic excellence, then it just might be that what matters is not how much we teach but how well, not how many problems students practice but how well students understand the problems, not how broadly students learn but how deeply.

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Appendix

The table shows the name of the first author, year the study was conducted, the grade of the students, the number of weeks the treatment lasted, the percent (%) correct that the teachers took as mastery, the achievement level of the students before the treatment, whether the school was public or religious, class size, the number of people in the treatment group, in the control group, in both groups, the lower end of a 95% confidence interval, the higher end, and the effect size. Only studies conducted in the United States were included. Mastery Learning studies based on special students, peer- or computer-assistance were excluded; the rational was to focus only on those studies which were most similar to what happens in Japanese classrooms (see Hedges & Waddington 1993). Group 4 (4th grade, low achieving students) of Burrows et al. was excluded, because the treatment was confounded with additional diagnostic tests. I also excluded one condition of Rubotvits' study (high achieving sixth graders), because an effect size of -5.32 seemed implausible and because the sample size (N = 6) seemed sufficiently low to cause the implausibility. The outcome variable was achievement in mathematics and was measured with tests constructed either by the teacher or the researcher (i.e., not standardized tests).

The results show a weighted effect size of 0.78, significantly hetrogenious, $X^2 = 17.87$, $P < 0.05$. No significant correlations were found between effect size and any other covariate, including those listed below, quality of the design of the study, year of publication, whether the study was published, a dissertation, or a presented paper.

1st Author & Year	Grade	Weeks	%	Ach.	P/R	Size	#ML	Cont	#Tot	Low	High	d
Anania 1981	4	3	80	Avg.	R	23	26	24	50	0.45	0.77	0.61
Anania 1981	5	3	80	Avg.	R	25	26	28	54	1.07	1.14	1.24
Anderson 1976	1-6	35	85	Avg.	P	?	195	195	390	0.62	0.66	0.64
Brace 1992	6	8	83	?	P	22	22	19	41	-.10	0.28	0.09
Burke 1983	4	3	80	?	R	32	31	32	63	0.67	0.93	0.80
Burke 1983	5	3	80	?	P	32	66	68	134	1.11	1.25	1.18
Burrows 1975	4	2	?	High	?	21	4	6	10	0.06	1.94	1.00
Burrows 1975	5	2	?	High	?	21	3	3	6	-.30	4.01	1.86
Burrows 1975	5	2	?	Low	?	21	6	5	11	0.79	30.3	1.91
Rubovits 1975	6	?	75	Low	P	15	7	3	10	-.04	2.08	1.02