HISTORY AND EFFECTIVENESS OF MASTERY LEARNING IN MATHEMATICS: FROM
B.F. SKINNER TO THE INTERNET
Content Preliminary Examination
Question #2
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Trace the history and effectiveness of mastery learning in mathematics from 1970 to the present. Compare and contrast modern approaches to the traditional approaches initiated by B.F. Skinner. Include both qualitative and quantitative details as appropriate. Include any meta-analytic studies that may exist.
Introduction

The mathematics achievement of middle and high school students in the United States is an issue of concern to educators and policy makers. The influential book *The World is Flat* (Friedman, 2005) claimed that secondary mathematics achievement is one of the key predictors of a nation’s long-term economic potential. The National Mathematics Advisory Panel (2008) argued that to continue to progress in mathematics achievement, we must improve the quality of math instruction received by all secondary students. Although many factors affect a student’s mathematics learning, one factor over which schools have the most immediate control is the choice of mathematics program to be implemented by teachers, administrators and curriculum developers.

One option is mastery learning. Mastery learning (Block & Anderson, 1975) is an approach to learning intended to bring all students to a pre-established level of mastery on a set of instructional objectives. Students are taught to well-defined objectives, formatively assessed, given corrective instruction if needed, and then summatively assessed. This model provides teachers with timely feedback about the progress and deficiencies of students in meeting specific instructional goals and presents a curriculum that provides extra time and opportunities for all students to gain mastery.

Federal efforts to improve American students’ achievement through high-stakes testing and the No Child Left Behind (NCLB) legislation have led to significant concerns about the fairness and effectiveness of standardized tests. Many of these concerns regard the use of summative tests to assess academic progress without the benefits of an effective formative model of assessment and instruction. Administrators, politicians, teachers, and students from a number of states are concerned about assessment requirements of NCLB. These requirements, which
include annual summative testing of students in third to eighth grade including once in high school in mathematics and reading, are designated by educational leaders in nearly all states. The federal goal is for all students to score at or above grade-level proficiency according to state standards by the end of the 2013–2014 academic year, and a lack of adequate yearly progress toward this goal can lead to sanctions (U.S. Department of Education, 2001). However, these summative results do not indicate growth by individual students from one year to the next. Instead, a static model is used to determine proficiency of cohort groups of students. This model has become a source of concern because it does not credit schools for substantial academic improvements. To rectify this problem, states have petitioned the U.S. Department of Education (Johnson, 2007) to use a growth criterion for evaluating educational progress. A growth model involves assessing each student before and after instruction to determine changes in achievement during the course of the school year (Zimmerman & Dibenedetto, 2008). This growth model aligns well with the philosophy of a mastery learning model.

Definitions and Theory of Mastery Learning

The defining characteristic of a mastery learning method is the establishment of a criterion level of achievement held to represent "mastery" of a given concept or skill. This is measured by frequent assessments of a student’s progress toward the mastery criterion with opportunities for corrective instruction, enabling students who do not initially meet the mastery criterion to do so on later analogous assessments (Block & Anderson, 1975). A mastery criterion usually in the range of 80% correct is established for the assessments. Corrective instruction may take the form of tutoring by the teacher, teacher aides, student tutors or by students who did achieve at the criterion level. Also, small group sessions may be formed in which students
review skills or concepts missed. In addition, alternative activities or materials may be created for students to complete independently (Bloom, 1976).

The theory upon which mastery learning is based is quite compelling. In hierarchically organized subject such as mathematics, failure to learn prerequisite skills is likely to interfere with students' learning of later skills. The challenge of covering the entire mathematics syllabus while accommodating the needs of struggling students creates an almost impossible situation. Consequently, many students move through the mathematics curriculum with deficiencies. Students stumble through the mathematics curriculum with these gaps in learning, gaps that seem to grow exponentially, until finally, frustrated by continuous failure, many drop out. Programs using mastery learning effectively are based on the theoretical premise that all children can learn when provided with conditions appropriate for their learning. The instructional strategies associated with mastery learning are designed to realize that belief in modern classrooms (Guskey & Pigott, 1988).

One key component of mastery learning is frequent and brief formative assessments that guide both learning and instruction (Guskey, 2005). These assessments provide both the students and the teachers with feedback about whether a particular goal has been mastered. Students who do not meet the criteria for mastery are given correctives, such as alternative worksheets, peer-tutoring, computer aided instruction, or other varied learning tools. On completion of the correctives, the students take a second formative assessment. If they also fail to pass this test, they are given additional opportunities to study and retake the test. Therefore, virtually all students achieve mastery before moving to the next unit. Students who have demonstrated mastery on the initial assessment are provided with enrichment material or offered the
opportunity to proceed through the curriculum at an accelerated pace (Zimmerman & Dibenedetto, 2008).

The premise is that if instruction is directed toward ensuring that nearly all students learn each skill in a hierarchical sequence, then students will have the prerequisite skills necessary to enable them to learn the concluding skills. Rather than accepting the idea that differences in student aptitudes will lead to corresponding differences in student achievement, mastery learning theory holds that instructional time and resources should be used to bring all students up to an acceptable level of achievement. To paraphrase, mastery learning theorists suggest that rather than holding instructional time constant and allowing achievement to vary as in traditional instruction, achievement level should be held constant and time allowed to vary (Carver, 1974).

**B.F. Skinner**

The theory of B.F. Skinner is based on the idea that learning is a function of change in explicit behavior. Changes in behavior are the result of an individual's response to events and stimuli that occur in the environment. A response produces a consequence, as illustrated in solving a mathematics problem. When a particular stimulus-response model is reinforced or rewarded, the individual is conditioned to respond (Skinner, 1968). In *The Shame of American Education*, Skinner states:

“Recent analyses of American schools and proposals for school reform have missed an essential point. Most current problems could be solved if students learned twice as much in the same time and with the same effort. It has been shown that they can do so (a) when the goals of education are clarified, (b) when each student is permitted to advance at his or her own pace, and (c) when the problem of motivation is solved with programmed instructional materials, so designed that students are very often right and learn at once that they are. The theories of human behavior most often taught in schools of education stand in the way of this solution to the problem of American education, but the proposal that schools of education simply be disbanded is a step in the wrong
direction. Teachers need to be taught how to teach, and a technology is now available that will permit them to teach much more effectively.” (Skinner, 1984, abstract)

Skinner is referring to mastery learning. Continuous frequent reinforcement is the key element in Skinner's theory. A reinforcer is anything that strengthens the desired response. It could be verbal praise, a good grade or a feeling of increased accomplishment or satisfaction.

Reinforcement theory contains several tenets that parallel mastery learning. This includes practice that takes the form of question/answer frames which expose the student to the objectives in gradual steps with immediate feedback. Questions should also be arranged so that the difficulty of the question falls within a student’s zone of proximal development, which refers to the range of tasks that are too difficult for a student to master alone but can be learned with guidance and assistance (Vygotsky, 1978). This is the point at which cognitive skill acquisition is optimized. The principles are that information should be presented and assessed in small amounts so that responses can be reinforced, and that positive reinforcement will be repeated and provide motivation.

Skinner claims that we need to program the subject matter. Material prepared for individual or mastery study first induces students to say or do the things they are to learn. Learning objectives need to be made explicitly clear. “Their behavior is thus ‘primed’ in the sense of being brought out for the first time. Until the behavior has acquired more strength, it may need to be prompted. Primes and prompts must then be carefully ‘vanished’ until the behavior occurs without help.” (Skinner, 1984, p. 951) At that point the reinforcing consequences of being right are the most effective in building and sustaining an enduring knowledge base. When students move through well-constructed programs at their own pace, the problems of motivation are automatically solved. Skinner claims:
“Students do not need to have a natural interest in what they are doing, and subject matters do not need to be dressed up to attract attention. No one really cares whether Pac-Man gobbles up all those little spots on the screen. Indeed, as soon as the screen is cleared, the player covers it again with little spots to be gobbled up. What is reinforcing is successful play, and in a well-designed instructional program students gobble up their assignments.” (Skinner, 1984, p. 952)

Abundant reinforcement is motivation enough, and is provided by good curriculum and instruction.

**Benjamin Bloom**

Benjamin Bloom’s seminal article “Mastery Learning” (1968) is now generally recognized as the classic theoretical formulation on the mastery model. Bloom made a number of specific and optimistic predictions about the gains from mastery learning procedures. One is that in classes taught for mastery, 95% of the students will achieve at the level previously reached by the top 5%. That means that typical scores in a mastery learning classroom should be approximately two standard deviations above the mean. Bloom has also argued that students do not have to put in much more time on school tasks to achieve this level of proficiency. Although students taught for mastery may need more time to reach proficiency in the initial stages of a course, they should need less time to master more advanced material because of the firm grasp of fundamentals that they should gain from their initial efforts. It has also been suggested that effects will be largest in mathematics and science since learning in these subject areas is generally more highly ordered and sequential (Block, 1971; Guskey & Gates, 1986).

Much like the NCLB concerns of today, Bloom was concerned with achievement gaps among different groups of students and directly referenced President Lyndon Johnson’s 1960’s era “War on Poverty” and focused directly on inequalities in the educational achievement of economically disadvantaged students and their more advantaged counterparts. Bloom argued that
to reduce variation in students’ achievement and to have all students learn well, we must increase variation in instructional approaches and learning time. That is, because students varied in their learning styles and aptitudes, we must diversify and differentiate instruction to better meet their individual learning needs. The challenge was to find practical ways to do this within the constraints of group-based classrooms so that all students learn well. Supporting the theories of B.F. Skinner, Bloom’s key element of mastery learning is well-constructed, formative classroom assessments. The approach would be for teachers to use their classroom assessments as learning tools, and then to follow those assessments with feedback and corrective procedures. In other words, instead of using assessments only as evaluation devices that mark the end of each unit, Bloom recommended using them as part of the instructional process to diagnose individual learning difficulties and prescribe remediation procedures (Guskey, 2005).

Summary of Research

Research Synthesis/Slavin, Lake & Groff, 2009

Effective Programs in Middle and High School Mathematics: A Best-Evidence Synthesis is a meta-analysis that reviewed research on the achievement outcomes of mathematics programs for middle and high schools. Study inclusion requirements included the use of a randomized or matched control group, study duration of at least 12 weeks, and equality at pretest. Six studies of mastery learning in mathematics met the criteria.
<table>
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<th>Sample Characteristics</th>
<th>Overall Effect Size</th>
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<td>7th and 8th</td>
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<td>9th</td>
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<td>Junior High</td>
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Overall, the synthesis found a weighted mean effect size of -0.05.

*Research Synthesis/Guskey & Pigott, 1988*

This paper, *Research on Group-Based Mastery Learning Programs: A Meta-Analysis*, presented a synthesis of findings from 36 mathematics studies on group-based applications of mastery learning strategies. Meta-analytic procedures were used to combine the results of the studies and to calculate estimates of the effects of group-based applications. Mathematics studies included basic math, general math, consumer math, algebra, matrix algebra, cartography, fractions, geometry, graphs, and probability. Studies in mathematics yielded a somewhat large weighted average effect size of 0.70. The larger effect size compared with the Slavin, Lake & Groff (2009) is most likely due to the much less rigorous inclusion criteria of the study.

Another aspect of the meta-analysis was the effects on teachers. In general, the synthesis found that teachers and teaching interns expressed much more positive attitudes toward the philosophy and practices of mastery learning after they had used these practices.
**Research Synthesis/ Kulik, Kulik & Bangert Drowns, 1990**

Although this synthesis did not report overall effect sizes for mathematics, there were interesting results related to student attitudes in general. Eighteen studies examined student ratings of the quality of the instructional method used in the course. Sixteen of the eighteen studies found more positive attitudes, and two studies found more negative attitudes in the mastery learning class. Overall, the average effect size in the 18 studies was 0.63. Likewise, fourteen studies examined the effects of mastery programs on student attitudes toward the subject matter that they were being taught. Twelve of these 14 studies reported that student attitudes were more positive in mastery classes than in conventional classes (with two studies finding negative effects). The average effect size for student attitudes toward subject was 0.40.

**Research Study/Zimmerman & Dibenedetto, 2008**

This 2008 qualitative study of a mastery learning mathematics curriculum in Algebra I was performed at Dryersburg High School located in a town of 17,406 residents near the Mississippi River has an enrollment of 886 students across the four grades. More than 40% of the students at Dryersburg High School are eligible for free and reduced lunch, and the curriculum is organized on a quarter-year round system. Chapters or modules are broken down into smaller units. Students are tested after each unit and must score 80% or higher to achieve mastery. Students who do not pass are then given correctives and retested. Students are provided the opportunity to retake a unit three times. The correctives tests focus on class material that had not been passed.

One teacher commented, “The biggest plus is that when they finish the year, they remember what they have learned. They don’t forget it. In addition, students participating in the mastery learning curriculum feel good about their learning and gain self-confidence in their
ability to earn a B or an A in math, an academic subject with which many had previously struggled (p.214).” Teachers in this program also reported that the organizational skills used to attain mastery in math class appeared to generalize to other classes. The teachers indicated that with the mastery learning curriculum they had higher expectations for their students and expressed a sense of empowerment and satisfaction in their ability to educate student. The study concludes that in the traditional approach of teaching algebra, students do not know exactly what is important and may feel overwhelmed and anxious by the amount of material to be studied in preparation for the one time summative exam. In contrast, mastery learning procedures focused students on the exact competencies that will be tested. Unlike traditional students’ apprehensions about testing, the mastery learning students at Dryersburg High School reported a high sense of confidence and self-efficacy for math, high self-evaluative satisfaction with their progress, and high goal standards. The teacher concluded that, “And you know that is the main thing, when kids experience success, they’re willing to work harder. (p.214)”

Limitations

Critics of mastery learning present some compelling arguments. First, if some students take much longer than others to learn a particular objective, then either corrective instruction must be given outside of regular class time, or students who achieve mastery early on will have to spend considerable amounts of time waiting for their classmates to catch up. Critics would state that the first case, extra time outside the classroom, is expensive and difficult to arrange, as it requires that teachers or tutors be available outside of class time to work with the deficient students. The latter case of having advanced students wait for classmates is just as troubling.
Second, the possibility that experimenter-made tests will be biased toward the objectives taught in experimental groups exists in all educational research that use such assessments, but it is particularly problematic in research on mastery learning, which by its nature focuses teachers and students on an explicit and narrowly defined set of objectives. When careful control of instruction methods, materials, and tests is not exercised, there is always a possibility that the control group is learning valuable information or skills not learned in the mastery learning group but not assessed on the experimenter-made measure (Slavin, 1987).

Technology in Mastery Learning

One recent report found that 50% of high school students are bored every day in their classes and that 82% of California 9th- and 10th-graders reported their school experiences as irrelevant and boring (Hart, 2006). Changing these deeply ingrained attitudes about learning will mean changing both the process of teaching and learning and the reward system for successful completion of schooling. Kids today spend over 6 hours per day interacting with television, video games, the Internet, instant messaging, email, and other media (Collins & Halverson, 2009).

Educational technology and mastery learning in mathematics are a natural partnership. One of the limitations of mastery learning is the issue of having to hire tutors or have teachers spend extra time with deficient students. This can be remedied by having corrective materials online available anytime and anywhere that an Internet connection is available. Likewise, more advanced students can proceed by accessing curriculum materials online. For example, TeacherTube is a video posting site similar to YouTube, but solely for educational content.
Mastery learning teachers can post lesson videos that students can view at anytime as well as review and rewind as needed (Bonk, 2009).

Another critique of mastery learning in mathematics is that concept may be sacrificed for manipulative skill (Kennedy, 1990). In terms of mathematics, technology can carry out all of the algorithms that students spend so much time learning in school. At the same time, learning to think mathematically is more important than ever (Collins & Halverson, 2009). Bloom also emphasized the need for instruction and assessments in mastery learning classrooms to focus on higher level learning goals, not simply basic skills. He noted:

“I find great emphasis on problem solving, applications of principles, analytical skills, and creativity. Such higher mental processes are emphasized because this type of learning enables the individual to relate his or her learning to the many problems he or she encounters in day-to-day living. These abilities are stressed because they are retained and utilized long after the individual has forgotten the detailed specifics of the subject matter taught in the schools. These abilities are regarded as one set of essential characteristics needed to continue learning and to cope with a rapidly changing world.” (Bloom, 1978, p. 578).

Understanding mathematical concepts in a mastery learning program may have been complicated in a pencil and paper era where active lessons, assessments and correctives were difficult, if not impossible. However, with Internet based learning, mastery teachers are able to provide dynamic lessons and correctives using online videos and software that presents the material using multiple representations and customized correctives to the individual student’s deficiencies.

Conclusion

To overcome inequities in mathematics instruction, the National Council of Teachers of Mathematics stresses the use of assessments that support learning and provide useful information to both teachers and students (NCTM, 2000). Feedback alone, however, does little to help
students improve their learning. Significant improvement requires the feedback be paired with effective correctives and activities that offer guidance and direction to students on how to remedy their learning problems (Bloom, 1976). Mastery learning in mathematics combined with educational technology may be one effective way of realizing this goal.

Although the literature shows mixed results for mastery learning in mathematics, the overall effect size is positive. This implies that mastery learning in mathematics is at least as effective as a traditional classroom. Furthermore, the studies were done before the age of the Internet which provides the possibilities for robust, active and dynamic mastery learning tools and assessment. Equally important, the effects of mastery learning are evident not only in measures of student achievement but also show positive effects in students’ attitudes towards the subject and the instructional method. As Skinner stated in his Pac-man metaphor, mastery learning can provide a new enthusiasm for students to be successful in mathematics based on an intrinsic motivation to “get to the next level.” Likewise, mastery learning relieves a student’s mathematics anxiety and develops their confidence when students know they can retest (Kennedy, 1990). Students learn to appreciate the objectives-based mastery design and become experts at mastering specific verifiable learning objectives. Education leaders are enthusiastically looking at new ways of linking Internet age media and education. Mastery learning in mathematics may be a viable focal point for this merging of education and technology.
References


