REVIEW

A Practical Review of Mastery Learning

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Objective. To review mastery learning and provide recommendations for implementation in a competency-based curriculum.

Findings. Mastery learning, introduced in the 1960s, was developed to ensure all students reach a desired level of mastery or competency. In this model, students acquire knowledge, skills, or attitudes and then complete formative assessments on that learning. If they achieve the desired level, they can proceed to enrichment activities. Students who do not meet the desired level of mastery proceed through corrective activities and retesting. Evidence suggests students within a mastery learning model perform better academically than those in nonmastery learning models with moderate effect sizes. Mastery learning may result in better performance due to several theoretical reasons, including aspects of motivation, testing, and feedback.

Conclusion. We make several recommendations on how to modernize mastery learning for apply it to the pharmacy education, including the recommendation to use more cumulative testing and assessment of baseline knowledge and skills. In addition, models of successive relearning may be applied to this model.

Keywords: mastery learning, competency-based education, successive relearning, remediation, outcomes-based education

INTRODUCTION

Competency-based curriculum is a type of outcome-based education that focuses on students’ abilities to do job-related tasks, promotes learner centeredness, and de-emphasizes time-based training.1 The continual movement toward competency-based education in the health sciences brings new tenets, the first of which is that the graduate should be competent in a diversity of abilities across various domains and a variety of contexts.

Competency is the observable ability of the pharmacist to integrate their knowledge, skills, values, and attitudes.2 Being competent means the learner possesses the required abilities in all domains in a certain context at a defined stage of pharmacy education or practice. Thus, competency-based education balances a curricular structure based in opportunity (eg, just-in-time learning) and time-based learning (eg, everyone proceeds at the same pace through a curriculum) with flexibility (eg, students proceed at their own pace). One instantiation of competency-based education is the mastery learning model. The mastery learning model can balance time-based learning with flexibility because of its corrective pathways. It also can balance structured learning with more opportunistic learning.

Overview, Effects, and Theoretical Underpinnings of Mastery Learning

In the 1960s, Bloom determined that the most efficacious learning situation was one-on-one tutoring.3 One-on-one tutoring starts with the student gaining an understanding of material, and, after that acquisition, their understanding is assessed through a formative assessment. If a concept is unclear to the student, the teacher or tutor provides feedback and exercises to enhance understanding (ie, corrective activities). Only when the student demonstrates adequate knowledge of the content (ie, mastery) does the teacher or tutor present new material. Thus, each student would move through the learning sequence at their own rate depending on how quickly they acquire the desired knowledge or skills. If this model of instruction is the most efficacious, then the challenge to instructors and curricular designers is to find practical ways to better meet individual learning needs in a group-based classroom. The concept of mastery learning attempts to address this challenge.
Mastery learning’s goal is for all or nearly all students to “master” or become competent in the course material. For the system to be successful, the instructor must clearly define the learning outcomes and what constitutes mastery for students. Each topic or grouping of topics (e.g., instructional units) organizes learning outcomes into one- or two-week intervals, and the structure of these units is displayed in Figure 1. Following the initial instructional period, students complete a formative assessment based on the established learning outcomes. For students who accomplish the predefined level of mastery, enrichment activities are offered to supplement the students’ understanding of the material. Conversely, students who do not accomplish the predefined level of mastery are given corrective exercises specific to the concepts missed by the student. These students are then given a separate formative assessment, pertaining to the same learning outcomes, and must demonstrate mastery prior to moving to the next unit. That is, students who do not accomplish mastery the first time are remediated until they demonstrate mastery.

As mentioned, mastery learning involves several steps: initial learning, formative assessment; corrective activities; and enrichment activities. The first step is to specify learning goals or objectives. Next is developing formative assessments, which provide students with feedback on their progress toward achieving the learning outcomes. The goal of a formative assessment to correct any learning difficulties (e.g., errors, misunderstandings) from instruction and direct future study. These assessments can be any format but should align with the learning objectives in terms of complexity and format. That is, if the learning objective states that students should complete an open-ended assessment that is focused on application of knowledge, then the formative assessment should be open-ended and focus on application of knowledge. The final step is developing summative assessments.

In the first step, specifying learning goals or objectives, instructors make judgements on what new concepts, knowledge, or skills are important for all students to learn well. This also involves deciding the level at which students should be able to work with this new information, such as the level of simple recall, applying new or different skills to a problem, or synthesizing information. These learning objectives can be constructed with the SMART objective (specific, measurable, achievable, realistic, and timely) or the Mager model. The Mager model includes the minimum acceptable performance and the context for that performance. As a comparison, a SMART objective may be, “By the end of this lesson, the student will be able to predict the changes in drug concentration given changes in clearance and volume of distribution.” The same objective in the Mager model would be, “Given an open-ended patient case, the student must be able to predict how drug concentrations will change in response to changes in clearance and volume of distribution with the acceptable level of performance as 80% correct.” The Mager model may be favored in competency-based education, as it defines the minimal standard or level of mastery (see Recommendations section).

The second step of designing mastery learning is the formative assessments, which provide students with feedback on their progress toward achieving the learning outcomes. The goal of a formative assessment to correct any learning difficulties (e.g., errors, misunderstandings) from instruction and direct future study. These assessments can be any format but should align with the learning objectives in terms of complexity and format. That is, if the learning objective states that students should complete an open-ended assessment that is focused on application of knowledge, then the formative assessment should be open-ended and focus on application of knowledge. The next part of the formative assessment is setting the standard for mastery. While many methods exist for standard setting (e.g., Angoff), most use a simple percentage. The literature recommends this standard be no lower than what may constitute a B, or 80%, or no higher than 90%, unless the task is so critical that it needs to be demonstrated at a high level (e.g., patient safety). Finally, the last part of this step is to create a second, parallel formative assessment to correct any learning difficulties from the first formative assessment.
assessment that measures the same objectives of the first assessment, with the same standards, but whose questions may vary in structure or format. This second assessment is used to check for success after corrective activities. For the formative assessments (and the summative assessment, see below), using blueprinting strategies can help with assessment consistency (see Recommendations section).

The next step is feedback and corrective activities. Because feedback provides insight on what the learner has mastered or done well and identifies areas for improvement, good feedback also provides direction on how a student can get better at areas that may be lacking. The corrective activities must involve a different type of engagement consistent with the literature on remediation. That is, if students learned the topic initially by reading, asking them to correct their knowledge with rereading is pointless. After students engage with the corrective activities, they can take the second formative assessment.

If students achieve the desired level of mastery on the first attempt, they can engage in enrichment activities, which should be rewarding and challenging to optimize motivation. Earlier in the semester, allowing all students to engage in these enrichment activities may help motivate students to do well in future units. In some cases, enrichment activities can be used for extra credit to incentivize completion.

The final step is developing the summative assessment. Per best practices, this assessment should be aligned with the learning objectives, formative assessments, and all instructional activities. Again, this can be part of the overall blueprint for assessment. Summative assessments determine the grade for the unit or course and would be appropriate to score using more traditional grading (eg, A=90%). All assessments are criterion based, aligned with the learning objectives, and ensure adequate sampling of these objectives.

Finally, the mastery approach requires the assignment of grades. Mastery learning lends itself to a pass-fail grading system, and Guskey recommended an honor-pass-fail system because it does not reward poor work but acknowledges going above and beyond expectations. Although, mastery learning can be adapted to other grading systems, the grading system still relies on matching the level of competency (achievement of outcomes) to the grade and does not reward things like participation. Deciding what is mastery or competency can be complex. For example, mastery or competency can be based on the amount of learning outcomes achieved (eg, competent on 80% of learning outcomes), or it can be based on mastering or being competent on each learning outcome as a set level (achieve an 80% correct on each learning outcome).

In summary, mastery learning stresses five things. The first is students will be graded solely based on their performance on the (final) summative assessment. Second, the student will be assessed on predetermined standards and not relative to peers. Third, students who attain the standard will receive the appropriate grade reward. Fourth, throughout learning the student will be given a series of ungraded, diagnostic assessments to promote and pace learning. And, finally, each student will be given all the help they need to learn.

Various studies have been conducted to compare mastery learning to other instructional strategies. Collectively, the literature supports mastery learning in terms of improved student achievement, final examination scores, attitude toward learning and content, and less variation in student performance. A meta-analysis of 36 mastery learning studies demonstrated an average effect size of 0.59, a medium to large effect. These effect sizes varied based on the properties of the courses. For example, courses with a higher “mastery threshold” had a larger effect size in terms of increasing student examination scores. Other differences that impacted effect size included subject matter, locally developed tests (vs nationally standardized tests), pace of the course, and extent of feedback. Of note, one meta-analysis included comparisons to studies using Keller’s Personalized System of Instruction (PSI), which is a system used in one-on-one tutoring, and, in general, the mastery learning model demonstrated greater effect sizes.

Whiting and colleagues showed an improvement in grade point average by almost one and a half grades (eg, C to a B+) in classes taught by mastery learning (n=7179). The average grade in classes taught by mastery learning was an A (with scores ranging from 97% to 99%), with only 1.5% of students (n=108) achieving a grade of F. A study by Marshall supported these findings with a 10% increase in average semester grade between the mastery learning course and the traditional course. This study also showed a reduction in formative assessment attempts throughout the course, demonstrating that students become more efficient at learning. Although difficult to quantify, Marshall also demonstrated the positive affective impact of mastery learning by comparing the perceived school climate and culture between students in a mastery learning course compared to those in a traditional course.

Although evidence demonstrates that mastery learning is beneficial in myriad ways, many potential reasons can explain why it works well. The theoretical underpinnings are that it creates a motivational environment, offers regular opportunities for retrieval practice, and focuses on feedback. The following paragraphs briefly review the theoretical underpinnings of the mastery learning model.
One overarching theme in mastery learning is establishing an environment that supports motivation. The self-determination theory of motivation has three aspects: autonomy, competence, and relatedness. Autonomy is the freedom to choose and involves the idea that when an individual has a choice, motivation increases. The autonomy aspect is present in mastery learning through the corrective activities, choice of completing enrichment activities, and the time limits of learning. As an example, in the ideal mastery learning model, struggling students would have a choice of corrective activities, encouraging them to feel motivated. Students also have the choice of whether to complete enrichment activities. Maybe most importantly, having flexibility in time also allows for choices, in that students have some flexibility to self-pace their learning and spend more time on areas of weakness and less time on areas of strength.

After autonomy, the second aspect of self-determination theory is competence. Here, the clear goal of mastery learning is to build competence. Again, for the struggling student, there is a pathway for competence despite initial poor performance. In theory, this could motivate students who may not think they would be able to “compete” for a grade otherwise. Yet, mastery learning does not let students off the hook in the same way that traditional instruction does. In traditional instruction, if a student does not complete an assignment, they would be assigned a failing grade, whereas in a mastery learning course, the student would receive an incomplete grade until they completed the assignment.

Finally, the last aspect of self-determination theory, relatedness, can be seen in the instructional activities and enrichment activities. In the normal classroom, higher-achieving students may not often be challenged to go above and beyond baseline expectations. For students who have demonstrated mastery of the unit content, offering enrichment activities allows for continued practice and unique ways to reinforce mastery of the learning objectives. Thus, the assessments and enrichment activities can be motivating if they are designed to help support students’ understanding of how the knowledge, skills, and attitudes will help them as future pharmacists. With the focus on goals related to the practice of pharmacy, this has positive effects on achievement and motivation.

While motivation is a large part of the mastery learning model, mastery learning also focuses on retrieval practice (ie, testing effect). At the end of each unit of instruction, a formative assessment is given, and it is well documented that these assessments are beneficial because of their ability to provide feedback. However, these formative assessments allow students to apply what they learned and serve as a retrieval opportunity, both of which improve learning and metacognition. For example, when students study a topic and are provided an opportunity to restudy the material or retrieve information (eg, complete an assessment), the students that retrieve information have better retention of material, with medium to large effect sizes.

Finally, the mastery model provides for repeated feedback. Feedback is an essential strategy for learning, leading to large effect sizes. In the mastery model, feedback is provided at each step, usually tied to an assessment. Giving explicit feedback in mastery learning courses allows the teacher to “prescribe” corrective exercises specific to each student’s learning situation. This minimizes the attention given to less necessary topics that students may have already mastered.

Recommendations and Implementation Strategies for Mastery Learning

Table 1 summarizes recommendations for implementing mastery learning. Mastery learning has stemmed from primary and secondary education, where the cycle of topic acquisition to corrective activities and enrichment activities has been effectively used in a single class period. In our view, this “microcycle” of mastery learning can be applied to health professions classrooms, but a longer macrocycle may be better suited for a competency-based curriculum. As a recommendation, the macrocycle may take days to weeks (Figure 2). One of the challenges in the mastery learning model is that, traditionally, mastery of a topic prevents students from moving on to the next topic, which may not be completely feasible in the classroom setting. Regardless, stop points can be implemented, and students still have to ability to self-pace, achieving competency at their own rate.

Mastery learning could be very adaptable to the model of successive relearning. In successive relearning, students practice the to-be-learned content until a designated level of mastery is achieved in each of multiple practice sessions (ideally three to four different study sessions). That is, a student would reach a mastery threshold on Day 1 and then again must obtain that level on subsequent study days. This can be incorporated into the mastery learning model because of the frequency of assessments. Thus, each mastery unit should include older material, and assessment should be cumulative (see later in this section and Table 1 for an example of quizzes, spacing, and blueprinting). Successive relearning, especially for conceptual material, has large effect sizes when measured by long-term retention. Therefore, it may not be necessary to have high levels of initial learning (eg, high initial competency thresholds) because if the course is built to be more cumulative and students must relearn material throughout, those initial mastery levels can be
Courses that want to maximize retention should avoid spending time and effort on learning to a high initial criterion (greater than 90%) but instead devote those resources to subsequent relearning sessions.

Another addition to modernize the mastery model is to activate prior knowledge through baseline testing or activities. Some proponents of mastery learning promote baseline assessment of knowledge and skills. This suggestion would be in line with the literature on the importance of prior knowledge being the basis for new learning. As such, bringing that baseline understanding to light can help customize the learning experience. Before each unit, a baseline test can help provide feedback regarding areas on which the student can focus for the upcoming unit and reactivate prior knowledge; this can be done with multiple-choice testing.

After a baseline assessment, the first traditional part of mastery learning acquiring knowledge, skills, values, and attitudes. In the mastery learning model, there is no specific guidance on how this occurs, and, as such, we can rely on current best practices. For knowledge acquisition, part of the strategy may be self-directed learning or guided self-paced instruction, as these may be most cost-effective because of their efficiency. This can be combined with peer-to-peer interaction (collaborative learning, peer instruction, cooperative learning) where students can discuss and generate their own understanding. Peer-to-peer instruction can help facilitate the application of knowledge, the development of skills, or the development of values and attitudes. Peer-to-peer instruction has a large effect size in meta-analyses.

During this acquisition phase, we can also apply components of retrieval and spacing like successive relearning. In the successive relearning model, students can test themselves on these key concepts and, when correct, can remove them from their study session. Then the next session, they retest the new and old concepts, and, again, when they correctly solve the problem or remember the key concept, they can drop it and repeat the cycle at some later time.

The last part of the acquisition phase can include opportunities for students to get questions answered from instructors or experts for the concepts that are still unclear. Here, key features include corrective feedback and modeling of the thought process.

The formative assessment’s goal is to manage learning. As such, these assessments occur in short intervals. After a topic is sufficiently learned, the formative assessment takes place and is a check to make sure students are making progress as they practice. This assessment should be no or low stakes. As with any assessment, it should be
appropriately blueprinted to ensure adequate sampling of the competencies (Table 2).45 Blueprinting would also help with any retesting to ensure consistency in assessing the learning objectives. The use of software packages (eg, ExamSoft) may facilitate the tagging of questions and allow for easier topic-level feedback. The threshold for this assessment should be high enough where the instructor feels students have learned enough to move on successfully but not too high as to make it unreasonable. We also recommend having these assessments be cumulative (see prior discussion on successive relearning).

Students who do not successfully achieve mastery after the first formative assessment should be given prescriptive feedback. Strong feedback is based on an observable task, is highly specific, and is based on standards.46 Feedback is most beneficial when it is provided for incorrect answers than correct answers, for correct answers when feedback is delayed, or correct answers when they are made with low confidence.31 Feedback should be tied to specific learning objectives to ensure corrective activities are tailored to a student’s situation. General feedback, for example, a score in percentage, is not helpful in diagnosing individual learning difficulties or prescribing remediation procedures.3 Thus, feedback needs to be specific. This feedback can be automated to some degree through most learning management software. Correction needs to involve strategies that differ from the original means of study.4 Like in the acquisition phase, various strategies can be used, such as self-explanation or instructional explaining or other methods that reduce misconceptions.47-49

In the area of retesting, the recommendations are to maintain the same blueprint as the original assessment. The timing of retesting may vary based on the time it takes students to study the material to pass. One strategy may be to include retesting material on future quizzes. The advantage is there is no need to have additional testing time, but the downside is the remediation session overlaps with the new learning session, which would be an additional burden for a struggling student. Remediation times could be set, in that students would have a fixed number of days to restudy and retest.50 This time could be used for the other students to complete enrichment activities. Another alternative is optional midterms. These would allow those that need to retest an opportunity to study and be tested and may give the other students an opportunity to earn points toward summative assessments.

For enrichment activities, it may be advantageous to pull in future course work that is related to a topic. First, this falls in line with competency-based education in that students can proceed at their own pace until they reach competency. By bringing some of the future work backward, those students that excel can learn more quickly. As mentioned, extra credit may be used to incentivize completion early on. Alternatively, completion of enrichment activities could be used to lower thresholds on summative assessments. Table 3 shows what a sample course may look like using the mastery learning model.

### Benefits and Potential Pitfalls

Poignant issues in education include disability (invisible and visible) and diversity, equity, and inclusion.
The sentiment that everyone can learn is apparent in the Universal Design for Learning (UDL) framework. The UDL framework has three principle components, namely to provide multiple means of representation (the "what" of learning), provide multiple means of action or expression (the "how" of learning), and to provide multiple means of engagement (the "why" of learning).51 The mastery learning approach addresses all three principles. For example, mastery learning addresses the "multiple means" principle because it typically has multiple ways for students to acquire the required knowledge, skills, and attitudes. Consistent with multiple means of engagement, if a student does not acquire mastery in the first attempt, the corrective activities will address a different method of instruction. Similarly, the various approaches to learning, the corrective activities, the enrichment activities, and the multiple chances and formats to demonstrate mastery capture all three principles. Because the UDL framework preceded the original work within the mastery model, there are scholarly opportunities to merge the two frameworks.

A concern with any course format is the issue of faculty workload. In the mastery model, there should be feedback, multiple versions of assessments, and overall tracking; with this comes the issue of workload. For feedback, there are numerous opportunities to automate feedback through learning management systems and other educational software (eg, ExamSoft). Assessments are linked to outcomes and reports generated on success of moving toward that desired outcome. While this may take upfront work, such a program would be reusable year to year. For multiple versions of assessments, this again may take upfront work but would be reusable year to year. There is less concern about assessment security because the goal is primarily for feedback and drive learning. The exception would be the summative assessments, which may require yearly updating, but this practice can be faculty dependent.

Another concern may be the impact of one course designed with a mastery learning framework or multiple courses in each semester and the student workload.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Topic</th>
<th>Acquisition</th>
<th>Assessment</th>
<th>Corrective</th>
<th>Enrichment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Single dose extravascular dose kinetics</td>
<td>5. Debrief Homework (feedback)</td>
<td></td>
<td></td>
<td>Dosing in Obesity</td>
</tr>
<tr>
<td>3</td>
<td>Continuous infusions</td>
<td></td>
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<td></td>
<td>Warfarin dosing</td>
</tr>
<tr>
<td>4</td>
<td>Multiple dosing</td>
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<td></td>
<td></td>
<td>Aminoglycoside dosing</td>
</tr>
<tr>
<td>5</td>
<td>Hepatic clearance</td>
<td>Same as above</td>
<td>Formative assessment using final exam–like questions; threshold 70% to pass</td>
<td>Formative assessment autopsy</td>
<td>Dosing in geriatrics</td>
</tr>
<tr>
<td>6</td>
<td>Renal clearance</td>
<td></td>
<td></td>
<td></td>
<td>Dosing in neonates</td>
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<tr>
<td>7</td>
<td>Multicompartment behavior</td>
<td></td>
<td></td>
<td></td>
<td>Dosing vancomycin</td>
</tr>
<tr>
<td>8</td>
<td>Nonlinear pharmacokinetics</td>
<td></td>
<td></td>
<td></td>
<td>Dosing in renal dysfunction</td>
</tr>
<tr>
<td>9</td>
<td>Pharmacodynamics</td>
<td></td>
<td></td>
<td></td>
<td>Antidepressant dosing</td>
</tr>
<tr>
<td>10</td>
<td>Integration and Review</td>
<td>Additional cases</td>
<td>Required. Formative assessment to help students prepare for final examination and may serve as third retest (if needed); need 80% to pass</td>
<td></td>
<td>Dosing in pregnancy</td>
</tr>
<tr>
<td>11</td>
<td>Practice assessment</td>
<td>Required. Formative assessment using final exam–like questions; threshold 70% to pass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Summative assessment</td>
<td>Required. Graded for high pass (&gt;90%), pass (&gt;75%), and fail (&lt;75%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The sentiment that everyone can learn is apparent in the Universal Design for Learning (UDL) framework. The UDL framework has three principle components, namely to provide multiple means of representation (the “what” of learning), provide multiple means of action or expression (the “how” of learning), and to provide multiple means of engagement (the “why” of learning). The mastery learning approach addresses all three principles. For example, mastery learning addresses the “multiple means” principle because it typically has multiple ways for students to acquire the required knowledge, skills, and attitudes. Consistent with multiple means of engagement, if a student does not acquire mastery in the first attempt, the corrective activities will address a different method of instruction. Similarly, the various approaches to learning, the corrective activities, the enrichment activities, and the multiple chances and formats to demonstrate mastery capture all three principles. Because the UDL framework preceded the original work within the mastery model, there are scholarly opportunities to merge the two frameworks.
Currently, a pharmacy curriculum may have multiple courses that use team-based learning or are flipped, which may involve similar dilemmas regarding how to manage student time. For example, one university has testing curriculum-wide, meaning each course is assessed with one test every few weeks, and then feedback and corrective activities are provided. The coordinated effort can help alleviate the additional work that may occur with several courses running independently. In schools of medicine, there are accreditation standards regarding monitoring student time. With appropriate oversight and guidance, setting limits on required (eg, preclass activities) and nonrequired elements (eg, general study) may be helpful in managing multiple classes.

CONCLUSION

Mastery learning has been associated with improved learning outcomes when compared to more traditional methods of learning. Mastery learning also has a strong theoretical basis. This framework may be a viable approach to address the desire for competency-based education, and more work is needed on four fronts. The first is on how to implement mastery learning curriculum-wide. Second, we need to know how mastery learning compares to the current “engaged” or high-structure instructional settings (eg, flipped classrooms or team-based learning). Third, we must know how mastery learning can be used to better communicate standards and achievement to outside stakeholders. Fourth, it is critical to understand how to best optimize mastery learning given the current evidence on best practices in education.

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