Study design: After the first six weeks of the semester, the approximately 430 students in Introductory Newtonian Mechanics were divided, based on homework scores, into two equally skilled groups. The groups were given related tutorial problem pairs (they both entailed the same concepts and methods), which they solved in opposite order relative to each other without any intervening problems. For example, if problem A was presented to one group followed by problem B, then problem B was presented to the other group followed by problem A. Thus, one group was unprepared for problem A while the other group was prepared for it by having solved problem B, and vice versa. The two groups were named prepared and unprepared relative to a tutorial problem pair under consideration. Six tutorial problem pairs were assigned for credit in the concept domains of linear momentum, energy conservation, angular motion, gravitation, torque, and rotational dynamics. (For more details, see R. Warnakulasooriya, D. J. Palazzo, and D. E. Pritchard, Evidence of problem-solving transfer in Web-based Socratic tutor, Proceedings of the 2005 Physics Education Research Conference, pp. 41–43; R. Warnakulasooriya, Evidence of Learning and Problem-Solving Transfer Successful learning must lead to problem-solving transfer—that is, the ability to apply what is being learned during one instance of problem solving to another instance in which a similar set of knowledge and methodologies is required.

Studies conducted using the Mastering programs show evidence of learning from Mastering’s tutorial items and from the ability gained by the students to transfer that learning where required.

Study 1. MasteringPhysics Introductory Newtonian Mechanics, Fall 2003 Massachusetts Institute of Technology

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Summary

In 10 of the 12 regular assignments given in MasteringChemistry, a linear decrease in problem difficulty occurs, with the earlier problems in an assignment being more difficult than the later problems. The average correlation between the problem difficulty and its order within an assignment is -0.26 ± 0.13. Thus, the difficulty of the next problem within an assignment effectively decreases by about 0.26 standard deviations. Since the student skill and the problem difficulty are placed on the same standard deviation scale in an item response model, this also suggests that the increase in skill from one problem to the next within an assignment is about 0.26 standard deviations.

With acknowledgments to Prof. David E. Pritchard, Massachusetts Institute of Technology; and Prof. Randall W. Hall and Prof. Leslie G. Butler, Louisiana State University.

Figure 1. The rate-of-completion graphs for a tutorial problem for the prepared and the unprepared groups plotted against the logarithmic time, where the time to completion is measured in seconds.

For the prepared group, the peak rate of completion is shifted toward shorter times compared with the unprepared group.
Study 2. MasteringChemistry
Introductory Chemistry, Fall 2007
Louisiana State University

Study design: The students were assigned weekly homework in MasteringChemistry. Twelve regular homework assignments were given (except the introductory assignment to MasteringChemistry) to the class, which consisted of about 260 students. The regular homework assignments had about 15 problems on average per assignment and the end-of-chapter (EOC) problems were always assigned after the tutorial problems within an assignment. A two-parameter item response model was fitted to the data scored dichotomously based on whether or not a student obtained the correct answer to a given part of a problem on the first attempt without requesting any help from MasteringChemistry, hence obtaining the difficulty and the discrimination parameters of the problem.

Results:
The difficulty of the problems against its position in the assignment correlates at -0.32 ± 0.09 on average for 10 homework assignments in which a linear association between problem difficulty and problem order in the assignment can be identified. Thus, the problem difficulty decreases over a given assignment. In other words, problems given later in an assignment are easier than the ones given earlier.


Three results were noted.
1. The prepared group solved a given problem on average 15 ± 3 percent more quickly than the unprepared group. This effect was observed across the six concept areas and hence on all of the 12 problems, providing robust evidence of learning from a prior problem leading to problem-solving transfer.

2. The prepared group requested 15 ± 6 percent fewer hints on a given problem compared with the unprepared group.

3. The prepared group made 11 ± 3 percent fewer errors on a given problem compared with the unprepared group.

Summary
Students engaging with the MasteringPhysics tutorials demonstrated learning and near-term problem-solving transfer as measured by the time to completion of problems, the number of errors made, and the number of hints requested on follow-up problems. The learning effect was a repeatable finding seen across the concept areas considered in the study (linear momentum, energy conservation, angular motion, gravitation, torque, and rotational dynamics).

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1 “The quickness” was determined by finding the time at which the highest rate of completion for the respective groups was observed and calculating the difference. Time to completion is defined as the time interval between the first opening of a problem and the submission of the completed problem in the sense that all the main parts of a given problem were answered correctly without any log-ins/log-offs.

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