Glossary of Terms as Used in These Abstracts

Confidence Interval Provides information on the range of most plausible population values based on a sample. For example, a 95% confidence interval will include the true population value within the intervals 95% of the time when the experiment is repeated many times.

Correlation The measurement of the amount of spread of a set of points around the regression line that best fits the points. If the points are scattered more around the best-fit line, the correlation will be less; if the points are closely clustered around the best-fit line, the correlation is high.

Effect Size A measurement of the increase or decrease in the average scores of an educational intervention in standard deviation units of the preintervention scores.

End-of-Chapter (EOC) Item In Mastering, EOC items do not have any hints, wrong-answer feedback, or follow-up comments associated with them.

Feedback Specific spontaneous responses provided by Mastering due to wrong-answer submissions. The feedback provided can be generic or specific. Feedback explains errors in the student’s reasoning but neither provides the correct answer nor explains how to achieve the correct answer.

Formative Assessment Used for obtaining information about a student’s current knowledge state so that appropriate instruction can be provided for the individual student or the class.

Item Response Model Provides characteristics of an item (problem), the most valuable characteristic being the difficulty of the item. When guessing is absent, the item difficulty is the skill needed to answer the item correctly with a 50% success rate. Item response models provide probability curves for items from which the chance of success on the items can be read at each skill level. Item discrimination—a measure of how well an item distinguishes more-skillful students from less-skillful students—and a measurement of the chance of guessing may also be obtained from basic response models.

Percentile Points A measurement of the increase or decrease in the average scores of an educational intervention in percentile units of the preintervention scores. If the scores are distributed normally, then a 34-percentile-point increase in scores is equivalent to an effect size of 1.

Problem-Solving Transfer The ability of the students to apply what is being learned during one instance of problem solving to another, similar instance.

Reliability The extent to which one set of items can be used in place of another set of items during assessment such that an educator may arrive at similar conclusions regardless of the particular item set used.

Summative Assessment Used for obtaining an overall sense of student or class achievement with respect to educational goals.

Tutorial Item In Mastering, tutorial items are multipart items comprising hints, specific wrong-answer feedback, and follow-up comments. They are designed to guide students toward the correct solution by actively engaging them in problem solving with scaffolding and providing the necessary conceptual and methodological knowledge.

Validity The extent to which assessment is an accurate reflection of the educational goals and the instructional methodologies utilized to achieve those goals.
Prediction of Final Exam Scores

Research has shown that the Mastering system-data can predict students’ final exam scores with a correlation of over 0.6. Overall, a student’s final exam score can be predicted with an uncertainty of less than one standard deviation with the current algorithms. This predictive ability provides instructors with the opportunity to provide personalized instruction for students at risk of failing the course.

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

Study design: The students were assigned weekly homework in MasteringPhysics and were given a paper-based final examination at the end of the semester. MasteringPhysics data for 236 students was applied to develop an algorithm that would take into account such variables as time to completion of an item, number of hint requests, and fraction of items solved in less than 2.5 minutes.

Results: The algorithm that was developed by using data obtained through MasteringPhysics predicts the paper-based final exam score with a correlation of about 0.64. The correlation implies that about 40% of the variance in the final exam scores is explained by the regression line. The statistical uncertainty in the correlation is between 0.52 and 0.69 with high confidence. See D. E. Pritchard and R. Warnakulasooriya, Data from a Web-based homework tutor can predict student’s final exam score, ED MEDIA 2005: World Conference on Educational Multimedia, Hypermedia & Telecommunications, pp. 2523–2529.

Figure 1. Correlation between the predicted versus the actual final exam score for 236 students at Massachusetts Institute of Technology in fall 2003 using MasteringPhysics.

This is comparable to the ability of the SAT math scores to predict freshman grade point averages, for which the correlation is about 0.5. Correlation values above 0.6 are generally considered as high while those below 0.3 are considered low.
Study 2. MasteringChemistry
Introductory Chemistry, Fall 2007
Louisiana State University

Study design: The students were assigned weekly homework in MasteringChemistry and were given a paper-based final examination at the end of the semester. MasteringChemistry data for 204 students was applied to develop a two-parameter item response model for answers scored dichotomously based on whether or not a student obtained the correct answer to a given part of an item on the first attempt without requesting help from MasteringChemistry.

Results: The application of the item response model predicts the paper-based final exam score with a correlation of about 0.68. The correlation implies that about 46% of the variance in the final exam scores is explained by the regression line. The statistical uncertainty in the correlation is between 0.57 and 0.74 with high confidence.

Summary
The predictive ability of the Mastering platforms aids instructors in confidently assessing students at risk of failing the course and provides the necessary remediation. “[Given the fact that a student is being assessed] over the course of the semester over several hundreds of problems with many variables that directly correlate with [the student’s] skill, it gives [a] better way to deal fairly with a student’s actual skill. This eliminates the high-stakes nature of a final exam. Given such assessment capabilities, teachers could confidently determine a student’s skill without worrying about the one who miraculously passed, deserved to pass, or failed, just because of some ‘bad luck.’”

Figure 2. Correlation between the predicted versus the actual final exam score for 204 students at Louisiana State University in fall 2007 using MasteringChemistry.

Summary
The predictive ability of the Mastering platforms aids instructors in confidently assessing students at risk of failing the course and provides the necessary remediation. “[Given the fact that a student is being assessed] over the course of the semester over several hundreds of problems with many variables that directly correlate with [the student’s] skill, it gives [a] better way to deal fairly with a student’s actual skill. This eliminates the high-stakes nature of a final exam. Given such assessment capabilities, teachers could confidently determine a student’s skill without worrying about the one who miraculously passed, deserved to pass, or failed, just because of some ‘bad luck.’”

2 D. E. Pritchard and R. Warnakulasooriya, Data from a Web-based homework tutor can predict student’s final exam score, ED MEDIA 2005: World Conference on Educational Multimedia, Hypermedia & Telecommunications, pp. 2523–2529.

With acknowledgments to Prof. David E. Pritchard, Massachusetts Institute of Technology, and Prof. Randall W. Hall and Prof. Leslie G. Butler, Louisiana State University.
The Power of Two-Way Learning

The importance of student-centered education, in which the needs of the individual student are identified for the achievement of mastery of a given subject, has been emphasized by educational researchers during the past century. Mastering’s unique platform augments the student-centered approach by adding a rich, data collection schema, whereby student interaction data with Mastering is captured and analyzed—both quantitatively and qualitatively—by subject-matter experts to provide the most effective online tutorial guidance.

By capturing student information in this way, Mastering’s Two-Way Learning system informs instructors with valuable data that they can then use to hone their teaching to best suit student needs. Assignment summary and diagnostic view screens organize individual, class, and systemwide data for convenient use at any time.

Simply put, Mastering incorporates a two-way learning process in which (1) students learn from the system and (2) the system in turn learns from the student interaction data. The knowledge obtained from the Two-Way Learning system provides instructors with valuable information about the individual student, further enhancing each student’s learning experience.

About These Abstracts

The Mastering system provides novel assessment opportunities and empowers us to couple our educational innovations with larger questions in education—or even with quantitative models of learning.

The following abstracts represent a sample of studies that instructors who used Mastering conducted independently or in partnership with Pearson to assess Mastering’s educational value. Some of the studies have been published in peer-reviewed journals and/or educational conference proceedings. The studies represent a variety of institutions in different content areas. We rely on extensive data mining and statistical analysis to arrive at our conclusions.

The studies fall broadly into the following categories:

- Score Gains
- Evidence of Learning and Problem-Solving Transfer
- Prediction of Final Exam Scores
- High Reliability of Assessment

We hope these brief abstracts inspire you to consider replicating a study or designing one unique to your school setting. If so, we look forward to hearing about your research.

Over half my class had test averages above 70%. That has never happened before.

—Prof. Linda Wilkes
Colorado State University–Pueblo

Pearson is to be complimented for conducting rigorous studies that investigate the impact of its Mastering products on student learning and outcomes. They have been insightful and thought provoking.

—Prof. Randy Hall
Louisiana State University

Pearson’s analysis of the performance of my general chemistry classes from the past two years provided me with invaluable insight about the effectiveness of MasteringChemistry. On the basis of this analysis, I was able to further refine my use of MasteringChemistry and feel that my class performance has exceeded that of last year.

—Prof. Robert Pribush
Butler University
Pearson’s Mastering Platform
What Instructors Are Saying

Assessment
MasteringBiology is a great method for assessing student comprehension. It leads to a better understanding of how students are thinking than would be observed in a standard quiz or exam.

—Prof. Michael Black
University of California, San Diego

I had the best test grades I have had in a long time. Students say MasteringChemistry has really helped.

—Prof. Carolyn Judd
Houston Community College

Diagnostics
The single greatest benefit to me as a professor is that I can see who is working and who is in trouble, and I can see globally what problems are causing difficulty.

—Prof. Gene Sprouse
State University of New York, Stony Brook

I have every intention of using MasteringChemistry again next fall. The average grade in my course this year went up considerably. In fact, this was the first year that final grades were not adjusted.

—Prof. Andrew McWilliams
Ryerson University

Ease of Use
Making assignments was very easy.

—Prof. Grant Mathews
University of Notre Dame

It’s clear my students are spending more time on homework as a result of MasteringPhysics. It’s also much easier for the instructor than the system we had been using.

—Prof. Michael Cherney
Creighton University

Tutorials
The tutorials are highly engaging, and the activities are varied enough to address multiple learning styles.

—Prof. Chris Romero
Front Range Community College

Whoever wrote the tutorials did a really good job. Students need more one-on-one attention, and MasteringChemistry gives it to them.

—Dr. Rosemary Loza
Ohio State University

Pedagogy
A truly amazing, outstanding combination of text and media!

—Prof. Carl Rutledge
East Central University

My students have written net ionic equations better than I have ever seen them do in more than 20 years of teaching. I think it’s because MasteringChemistry doesn’t accept “close” for an answer, and it gives students immediate feedback.

—Prof. Gary Buckley
Cameron University

Reduction of D/W/F Rates
Overall, students who completed assignments from MasteringChemistry scored 24% higher on exams than those who did not.

—Jason Hustedt, Online Administrator
University of Nebraska–Lincoln

By far the most useful, best-designed companion Web site I have ever used. My students’ understanding vastly increased by being able to interact with exercises and go at their own pace.

—Prof. Tom Fleming
University of Arizona
Pearson’s Mastering Platform
What Students Are Saying

Ease of Use
MasteringChemistry is so easy to use, any high schooler could understand it.

—Amy Tan
University of California, Davis

Increased Understanding
MasteringBiology is really helping me comprehend the material better.

—Veniece Staton
University of North Carolina, Greensboro

Now I understand how to do the work.

—Zach Armstrong
Auburn University

Because there are explanations on how to approach and solve the problem, I get a better understanding of the material I learned in lecture a few days ago.

—Howard Chu
University of California, Davis

My exam scores were significantly higher after using MasteringAstronomy, and I understand the material more fully.

—Heather Barnhart

MasteringPhysics made it much easier for me to relate physics to real-world situations.

—Erin DuPlessis
Chemeketa Community College

The movies and activities were informative and fun. And I really enjoyed the questions and puzzles that followed the video tutorials.

—Helena Amanda Vaynberg
California Polytechnic State University, San Luis Obispo

MasteringBiology was definitely critical for my learning. The Web animations helped me to understand complicated processes such as cellular respiration and photosynthesis.

—Brandon Knight
Keene State College

Instant Feedback
I really liked the immediate feedback and in-depth explanations I got in response to my answers.

—Siobhan Halloran
Carnegie Mellon University

It’s nice to have the freedom to make mistakes and learn from those mistakes immediately—without waiting for the assignment to be graded and returned.

—Lisa Clark

I like how the immediate feedback actually tells me why my answer is wrong. This makes learning and understanding the right answers much easier.

—Reece Cook

Interactivity
The visuals and interactivity in MasteringAstronomy make it very easy to learn the material.

—Adam Rousselle

MasteringAstronomy makes learning easy.

—Sarah Smith

Seriously, this was amazing. It helps so much to see it, and the interactivity actually makes learning fun.

—Kevin Lew
University of California, San Diego

I like the hints and interactivity. It’s like having a second teacher.

—Bo Vernon

Tutorials
I loved MasteringChemistry! The problems were very helpful, especially the hints. I liked the step-by-step guides and that each topic was introduced with the conceptual parts of the subject.

—Maria Saavedra
Loyola University

Textbooks give the answers to certain problems, but don’t help with why you got an answer wrong. MasteringChemistry helped me to learn from my mistakes rather than stay confused.

—Brittany Schieron
University of California, Davis
Study 2. MasteringBiology
Introductory Biology, Fall 2008
Monash University, Victoria, Australia

Studies: In 2008 students were assigned weekly MasteringBiology homework consisting of tutorials, multiple-choice questions, and selected readings in preparation for the lecture. A 15-minute open-book quiz was then given in Blackboard™ within 36 hours of the lecture. The quiz scores were compared with the year 2007, in which MasteringBiology had not been used in a similar course with the same instructor. Sequence, quiz length, question types and degree of difficulty, and time allowed for a quiz were kept the same in 2008 with MasteringBiology to allow for a fair comparison with 2007 in which MasteringBiology was not used. The final exams in both years were identical; students repeating the course were not included. Furthermore, entering students did not differ in any substantial way as judged by the university’s entrance rankings (75.1 in 2007 as opposed to 75.0 in 2008). The number of students in the course for each year is on the order of 600.

Results: In all of the 12 weekly quizzes, students who used MasteringBiology in 2008 outperformed those who did not use it in the previous year. The average quiz score gain was 6.4 ± 3.3 (95% confidence interval). Students who used MasteringBiology placed at the 62nd percentile on average in the final exam, which corresponds to an effect size of 0.3.

Summary
The consistency in score gains for students who used MasteringBiology in comparison to those who did not—across all of the quizzes and hence, across many concept domains in biology—is an educationally significant result. (For more details, see G. Rayner, Evaluation and student perception of MasteringBiology as a learning and formative assessment tool in a first year Biology subject, Proceedings of the 2008 Australian Technology Network Assessment Conference.)

With acknowledgments to Prof. Valerie Frerichs, University at Buffalo, and Prof. Gerry Rayner, Monash University.

Score Gains
Score improvements in the formative and the summative assessment stages represent an important indicator of the effects of an educational intervention. The assignment of Mastering homework shows that students were positively affected by its use in improved quiz and final exam scores.

Study 1. MasteringChemistry
General Chemistry, Fall 2008
University at Buffalo, State University of New York

Study design: In the years 2004–07 online homework was not used in General Chemistry courses. In fall 2008 MasteringChemistry was introduced for credit for online homework in the course. Historical comparisons were feasible since the course coverage and instructional components were comparable over the years. Fall-semester final exam scores for the years 2004, 2005, 2007 (without MasteringChemistry), and 2008 (with MasteringChemistry) were compared for students who completed the course within a given semester. The number of students in the course in a given year ranged from 912 to 1,125.

Results: Students who used MasteringChemistry in fall 2008 showed an improvement of 0.5 in effect size in the final exam in comparison to the years 2004, 2005, and 2007, in which MasteringChemistry was not used. In other words, the average student who used MasteringChemistry in 2008 is at the 69th percentile. Hence, in terms of percentile points, there is a 19-percentile-point improvement in the final exam score, on average, when students were assigned homework in MasteringChemistry.

More remarkably, students at each of the (score) quartiles (25th, 50th, and 75th percentiles) were positively affected by the use of MasteringChemistry in fall 2008 relative to the previous years. In particular, the probability that a student at the 25th percentile of the class would obtain a final exam score of 50 or above is 81%. That probability is less than 50% in the previous years (42% in 2004, 26% in 2005, and 17% in 2007) in which MasteringChemistry was not used.

1 The studies documented are observational in nature, as opposed to randomized controlled experiments, and thus attention has been paid to possible confounding factors in drawing conclusions.

2 The difficulty levels of the final exams across the years were assumed to be comparable. This is a reasonable assumption through it cannot be rigorously proven. The fall 2008 final exam scores were lower by about 0.1 standard deviations compared with the other non-MasteringChemistry years 2004, 2005, and 2007, and hence are not included in the analysis. According to the instructor, this may be due to an ice storm that hit the campus area on the day of the first exam, which led to its cancelation. This also deprived students from study for about two weeks. Though the ice storm did not occur during the final exam, it may have had a ripple effect as reflected in the fall final exam scores. The lower scores in 2008 may further support the argument that the final exams had comparable difficulties, since an easier exam to “compensate” for the ice storm would not have resulted in such a decrease.

3 It is difficult to adjust the observed effect size (0.5) for individual teacher influences in 2008 over and above teacher effects for the years 2004, 2005, and 2007. According to some research findings, an effect size of about 0.2 is attributable to the teacher in a traditional classroom setting, while various other teacher influences such as reinforcement, peer tutoring, class environment, and questioning would result in an average effect size of about 0.4. However, influences on student learning, J. Hattie, Inaugural Professional Lecture, University of Auckland. Thus, if the latter teaching methodologies were employed in 2008 in addition to the traditional settings in the previous years the teacher effect would account for 0.2 of the observed effect size. The resulting effect size attributable to MasteringChemistry would then be about 0.3, which would place the average student at the 62nd percentile.
Figure 1. The final exam score (historical) comparisons of students who did not use MasteringChemistry in the years 2004, 2005, and 2007 to students who used MasteringChemistry in 2008. Students who used MasteringChemistry showed a 0.5 improvement in effect size, which placed the average student at the 69th percentile. The errors shown are the 95% confidence interval of the standard error of the mean. The final exam scores are scaled to a maximum of 100%.

Figure 2. The final exam score (probability) distributions for a student at the 25th percentile. The probability that a student at the 25th percentile of the MasteringChemistry class in 2008 would obtain a score of 50 or above is 81%. That probability is less than 50% in the previous years (42% in 2004, 26% in 2005, and 17% in 2007) in which MasteringChemistry was not used. Graph legend: Green (2004), Blue (2005), Black (2007), Red (2008, with MasteringChemistry).

Figure 3. The final exam score (probability) distributions for a student at the 50th percentile. The probability that a student at the 50th percentile of the MasteringChemistry class in 2008 would obtain a score of 70 or above is 23%. That probability is less than 10% in the previous years (3% in 2004, 2% in 2005, and 2% in 2007) in which MasteringChemistry was not used. Graph legend: Green (2004), Blue (2005), Black (2007), Red (2008, with MasteringChemistry).

Figure 4. The final exam score (probability) distributions for a student at the 75th percentile. The probability that a student at the 75th percentile of the MasteringChemistry class in 2008 would obtain a score of 85 or above is 3%. That probability is three times as less in the previous years (1% in 2004, 0.5% in 2005, and 1% in 2007) in which MasteringChemistry was not used. Graph legend: Green (2004), Blue (2005), Black (2007), Red (2008, with MasteringChemistry).

Summary

The use of MasteringChemistry in the General Chemistry course in fall 2008 resulted in 0.5 effect size score gains in the final exam. Thus, the average student who used MasteringChemistry can be placed at the 69th percentile in relation to the previous years’ score distributions in which MasteringChemistry was not used. Though an observational study, the attribution of score improvements to MasteringChemistry is supported by the observation that the final exam score distributions (mean and variance) remained stable in the years 2004, 2005, and 2007 in which MasteringChemistry was not used. Students at each score quartile were positively affected by the use of MasteringChemistry. For example, the probability that a student at the 25th percentile of the class would earn a final exam score of 50 or above is 81%. That probability is less than 50% in the previous years in which MasteringChemistry was not used. Thus, students who were less skilled or were at risk of failing the course were positively affected by the use of MasteringChemistry. Similarly, a student at the 75th percentile who has used MasteringChemistry has three times as much chance of scoring above 85 than a student at the same percentile level who did not use MasteringChemistry.
High Reliability of Assessment

The high reliability of a set of items is a key ingredient for successful assessment. Reliability indicates the extent to which one set of items can be used in place of another set of items during assessment such that an educator may arrive at similar conclusions regardless of the particular item set used, provided that the items in both sets are valid for the particular assessment.

One measure of reliability is given by item difficulty. If an assessment is reliable, a given item should not be easier or more difficult than an item chosen to substitute it. Thus, the average difficulty of a set of items should more or less agree with the average difficulty of a set of items chosen in its place for a given student. The higher the agreement in difficulty between the two sets of items is for a given student, the higher the reliability of assessment on that student.

Higher reliability of assessment gives the instructor a higher confidence about the information obtained about a particular student or about the class as a whole to chart out individual or class instruction. Furthermore, assessment reliability is critical for the instructor to decide on the critical pass/fail cut off.

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

Study design: Sixty-four MasteringPhysics tutorial items given throughout the semester were randomly divided into two sets of 32 items each with one problem on a given conceptual domain in each. The average difficulty of a given set for a student was computed as a linear combination of the average values of time to first correct response, number of incorrect responses given when feedback is absent (except “try again”), and number of hint requests. The results were based on 325 students.

Results: The correlation between the average difficulty of the first item set and the average difficulty of the second item set is about 0.92 yielding a high reliability of about 96%. The high correlation implies that about 85% of the variance is explained by the

Figure 1. Correlation of average difficulty between two sets of tutorial items containing 32 items each showing the high reliability of assessment. A point corresponds to a single student.
regression line. In contrast, a similar study for problems in the paper-based final exam accounted for about 40% of the variance. (See D. E. Pritchard and E. S. Morote, Reliable assessment with CyberTutor, a Web-based homework tutor, World Conference on E-Learning in Corporate, Government, Health, & Higher Education, 2002, pp. 785–791.) Thus, MasteringPhysics data such as time to first correct response, number of incorrect responses without receiving feedback, and number of hint requests, can be used to reduce the measurement error by a factor of two. (The statistical uncertainty in the correlation is between 0.89 and 0.93 with high confidence, and therefore we can be fairly confident that we would obtain higher reliability values under repeated measurement under similar conditions.)

**Study 2. MasteringChemistry**

**General Chemistry, Fall 2006**

Randomly selected from the MasteringChemistry database

**Study design:** A General Chemistry class was randomly selected from the MasteringChemistry database, the only criterion being that the course comprise at least 300 students and at least 60 assigned tutorial items throughout the semester. The random selection avoided any biases that would be introduced if the study was conducted explicitly to verify the reliability of assessment. The 80 tutorial items given throughout the semester were divided randomly into two sets of 40 items each. The average difficulty of a given set for a student was computed as a linear combination of the average values of time to first correct response, the number of incorrect responses given when feedback is absent (except "try again"), and the number of hint requests. The results were based on 347 students.

**Results:** The correlation between the average difficulty of the first item set and the average difficulty of the second item set is about 0.85 yielding a high reliability of about 92%. The high correlation implies that about 72% of the variance is explained by the regression line. (The statistical uncertainty in the correlation is between 0.80 and 0.89 with high confidence, and therefore, we can be fairly confident that we would obtain higher reliability values under repeated measurement under similar conditions.)

**Summary**

Mastering content offers highly reliable assessment (over 90%) as evidenced by the aforementioned two studies. Such high reliability aids instructors by providing a high level of confidence in Mastering content and assessments in that information provided by Mastering, whether on an individual student or the class as a whole, is validated for further intervention and instruction.

*With acknowledgment to Prof. David E. Pritchard, Massachusetts Institute of Technology.*
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

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.)

It is highly plausible that the decrease in problem difficulty is due to an overall effect of learning within a given assignment. The instructor followed the best practice recommendations given in MasteringChemistry and selected a roughly equal number of tutorials and EOCs as much as feasible within an assignment. The tutorial and EOC problems were selected so that they covered important parts of each chapter. Though the 1 (easy) through 5 (hard) difficulty scale was not actively used by the instructor in selecting the problems from the MasteringChemistry’s item library, the problems selected mainly fell in the difficulty range 1–3. Even if the EOC problems that were assigned at the end of an assignment were inherently easy, the general negative correlation does not explain the decrease in difficulty we see among the tutorial problems along the order. Since the instructor did not consciously select problems in decreasing order of difficulty within an assignment, it is reasonable to infer that on average we see a learning effect from one problem to the next within an assignment. The average decrease in difficulty per problem 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.

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 -0.32 ± 0.09 while the decrease in difficulty from one problem to the next is -0.26 ± 0.13 standard deviations. Hence, the learning effect attributable to a problem 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.

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 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.

Results: 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.

![Figure 2. Prepared group solves a given tutorial problem in 15 ± 3% less time on average compared with the unprepared group.](image)

![Figure 3. Prepared group solves a given tutorial problem with 11 ± 3 percent fewer errors compared with the unprepared group.](image)

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).

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.

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).

Figure 2. Prepared group solves a given tutorial problem in 15 ± 3% less time on average compared with the unprepared group.

Figure 3. Prepared group solves a given tutorial problem with 11 ± 3 percent fewer errors compared with the unprepared group.

**Notes:**

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.

2 The difficulty 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.

3 “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.