### Key Results
Students in this study who skipped fewer Mastering Chemistry assignments tended to do better on the final exam than students who skipped more assignments, and there was a strong positive correlation ($r = 0.61$) between average Mastering Chemistry homework scores and final exam scores.

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Submitted by
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Course materials
Mastering Chemistry and Chemistry: The Central Science, Theodore E. Brown, H. Eugene LeMay, Bruce E. Bursten, Catherine Murphy, Patrick Woodward, and Matthew E. Stoltzfus

Setting
The University of North Florida is a four-year public university that was established in 1972 and today serves approximately 16,500 students. Between fall 2008 and fall 2012, first-year retention rates ranged from 81 percent to 84 percent for those starting at the school. Graduation rates for the same period ranged from 46 percent to 49 percent.\(^1\) From 2010 to 2012, at the undergraduate level, 32 percent of the degrees awarded were in areas of strategic importance to the local economy, including degrees in health sciences and STEM.\(^2\)

Associate Professor Michael Lufaso has been teaching General Chemistry I since he started at the school in 2006. He has taught General Chemistry II since 2009.

General Chemistry II is a three-credit course, and the second course in a two-semester sequence taken primarily by biology and chemistry majors. The course covers the chemistry of gases, liquids, and solids; thermodynamics; electrochemistry; aqueous equilibria; and reaction rates. The one-credit lab is a separate course, which most students take concurrently with lecture. It is suggested, but not required, that students take the lab as a corequisite.

General Chemistry II is taught only as a face-to-face lecture. Approximately 175 students take the course per semester during the academic year; and an additional 100 students take the course during the summer semester. The majority of students who take the course are required to do so for their program, so successful completion is important. The biology program is limited access, so students must successfully complete this course to be admitted to that major. Other majors that take this course include nursing, nutrition, and premedical. This study includes data from Lufaso’s sections only.

Lufaso incorporates the following learning objectives.

- Know the world.
- Demonstrate knowledge of the natural sciences.
- Apply knowledge to real-world situations.
- Recognize the inevitable limits of your own perception and understanding. Think critically.
- Read, analyze, and understand complex texts or quantitative information.
- Solve problems.
- Locate, evaluate, and/or use research sources.
- Formulate and/or apply models to evaluate problems and draw conclusions.

Challenges and Goals
Students who take this course tend to have a diverse set of skills and bring a variety of backgrounds; some have gaps of time between General Chemistry I and II. Since chemistry is a cumulative subject and new material builds upon a series of linked concepts, Lufaso believes that concept repetition and practice are critical for student achievement. Because many students must complete this course to move forward in their program, Lufaso sought a way to both identify areas of weakness and misconceptions and provide resources that would enable students to fill...
知识缺口并提供必要的练习以取得成功。他于2007年采用Mastering Chemistry来解决这些需求。

由于结果，Lufaso参与了这项研究，以开始测试和衡量（1）持续重复以填补知识缺口和（2）表现之间的关系。为开始测试学生在预讲和后讲实践中的方式，Lufaso收集了相关数据，这些数据与Mastering Chemistry作业有关，他相信这些数据将对课程的学习成果有所帮助并与其学习目标一致。

实施

自从2007年首次采用Mastering Chemistry以来，Lufaso的实施方式随着新功能的加入和他对资源的熟悉而发生改变。他认为，主要的学习任务是为学生提供一个机会来回顾和弥补在讲座和教科书中覆盖的概念，并给学生一个练习和测试他们对考试的准备程度的机会。他还利用诊断信息来监测错误率最高的问题，以便能够在课堂上深入地解决这些问题。

在最初的几年中，Lufaso仅在讲座之后分配章节作业。表1显示了从2007年到2014年，包括预讲、可选的Adaptive Follow-Up，以及可选的实践作业的实施变化。

对于2014年秋季学期，Mastering Chemistry作业包括以下内容：

**Prerequisite knowledge assignment.** 第一个要求分配的学期涵盖了概念从General Chemistry I。一个可选的Adaptive Follow-Up任务分配是可选的，因此学生可以弥补错过的基础概念。

**Prelecture assignments.** 这些要求分配都是为了鼓励在讲座之前阅读。它们包括了少量问题，通常是为了额外的学分，而且通常包含阅读问题。它们不是计时的，必须在讲座之前完成，并且允许多次尝试。对于多项选择，应用了标准的计分方法（100%/(# of answer options – 1)）来防止学生猜测。所有其他问题通常是以8%的不正确答案为误扣的。

在讲座之前，Lufaso回顾了完成的预讲分配的诊断结果，以便更好地理解学生在课堂上关注的概念。他还使用诊断信息来改进讲座笔记和计划课堂活动来增强学生对难点概念的理解。这些活动帮助学生在尝试讲座章节分配之前理解错觉。

**Postlecture chapter assignments.** 这些要求分配是在讲座之后的章节内容被涉及一周后完成的。分配包括了辅导和活动问题，以及其他问题类型。通常，一个辅导问题被跟在了每章问题之后。允许尝试的次数最多为六次，不是计时的。

<table>
<thead>
<tr>
<th>Time Period</th>
<th># of MC Postlecture HWs</th>
<th># of MC Prelecture HWs</th>
<th># of MC Practice Assignments (Optional)</th>
<th># of MC Adaptive Follow-Up Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007–11</td>
<td>~10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>10</td>
<td>7</td>
<td>11</td>
<td>0</td>
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<td>2013</td>
<td>10</td>
<td>19</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>2014</td>
<td>10</td>
<td>~19</td>
<td>~11</td>
<td>9</td>
</tr>
</tbody>
</table>

表1. Mastering Chemistry实施，2007年秋季至2014年秋季

Lufaso的[Mastering Chemistry]实施已经改变，因为新功能被加入并他变得更熟悉资源。
**Adaptive Follow-Up assignments.** Optional Adaptive Follow-Up assignments were intended to address knowledge gaps. They were generated by Mastering Chemistry based on each student’s performance on postlecture chapter homework. Assignments were due two days after the chapter assignment for extra credit. Students who earned a 95 percent or higher on the Mastering Chemistry chapter assignment tested out of the optional assignment and automatically earned full extra credit.

**Practice assignments.** Optional chapter problems were available for additional practice.

Three exams and a comprehensive final were administered. The exam format typically consisted of multiple-choice conceptual questions and problems, multiple-part problems (multiple-choice format), matching, fill in the blank, drawing/sketching/graphing, and short-answer problems.

Exam questions were combinations of Pearson test bank and instructor-written questions. Term exams were 75 minutes, and the final exam was 110 minutes. Exam questions were similar to Mastering Chemistry homework questions. When providing answer keys after exams, Lufaso noted which questions were similar to specific Mastering Chemistry problems.

**Assessments**

<table>
<thead>
<tr>
<th>Points</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>Term exams (three)</td>
</tr>
<tr>
<td>275</td>
<td>Final exam</td>
</tr>
<tr>
<td>250</td>
<td>Mastering Chemistry homework</td>
</tr>
<tr>
<td>25</td>
<td>Mastering Chemistry prerequisite knowledge</td>
</tr>
</tbody>
</table>

**Results and Data**

Fall 2014 data was analyzed to understand the relationship between use of Mastering Chemistry and learning and course outcomes. Seventy-one students were enrolled after the official withdrawal period. Seven students (10 percent) neither completed the course nor officially withdrew.

Of the seven students who did not complete the course, one did not take any of the four exams, and another student stopped after exam 1. Four other students stopped after exam 2. Another student did not take the final exam. Because these students did not complete the final exam, their data were excluded from the following analyses. For purposes of this analysis, a skipped Mastering Chemistry homework is one with a score of zero.

Results show a strong positive correlation between Mastering Chemistry scores (including all required and optional assignments), and the final exam score, with $r = 0.61$ (Figure 1).

Because Lufaso was interested in investigating the relationship between completion of Mastering Chemistry assignments and course performance, an analysis was done using exam 1 as a baseline. Students were divided into two groups based on the exam I median score of 74: low exam 1 (LE1) for students scoring less than the median and high exam 1 (HE1) for students scoring higher than the median (Table 2).

Mastering Chemistry homework participation was calculated based on the number of skipped assignments out of the 38 total required and optional assignments (prerequisite knowledge, prelecture, chapter, and Adaptive Follow-Up).

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**Figure 1. Correlation between Average Mastering Chemistry Scores and Average Final Exam Scores, Fall 2014 (n = 64)**

![Graph showing correlation between Mastering Chemistry scores and final exam scores.](image)

**Figure 2. Comparison of Average Exam Scores based on Mastering Chemistry Participation, Fall 2014 (n = 64)**

![Graph comparing average exam scores based on Mastering Chemistry participation.](image)
The average number of skipped homework assignments was 8.5. Students were assigned to groups based on whether they skipped fewer (high homework, HHW) or more (low homework, LHW) than the average of 8.5 skipped.

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEI/HHW</td>
<td>High exam 1/high homework participation</td>
</tr>
<tr>
<td>HEI/LHW</td>
<td>High exam 1/low homework participation</td>
</tr>
<tr>
<td>LEI/HHW</td>
<td>Low exam 1/high homework participation</td>
</tr>
<tr>
<td>LEI/LHW</td>
<td>Low exam 1/low homework participation</td>
</tr>
</tbody>
</table>

Table 2. Exam Performance/Homework Participation Groups

Figure 2 shows the exam averages by homework participation groups. Data indicated the following:

- HEI/HHW and HEI/LHW exam 1 scores were statistically equivalent. HEI/HHW (M = 86%; SD = 8%; N = 15) and HEI/LHW (M = 85%; SD = 7%; N = 18).
- By the final exam, HEI/HHW scores were 8 percentage points higher than the scores for HEI/LHW, a statistically significant difference (p < 0.05): HEI/HHW (M = 80%; SD = 14%; N = 15) and HEI/LHW (M = 72%; SD = 14%; N = 18).
- LEI/HHW exam 1 scores were 10 percentage points higher than LEI/LHW scores, a statistically significant difference (p < 0.05): LEI/HHW (M = 60%; SD = 11%; N = 14) and LEI/LHW (M = 50%; SD = 15%; N = 17).
- LEI/HHW final exam scores were 12 percentage points higher than LEI/LHW scores, a statistically significant difference (p < 0.05): LEI/HHW (M = 63%; SD = 17%; N = 14) and LEI/LHW (M = 51%; SD = 19%; N = 17).
- The difference between HEI/LHW and LEI/HHW was 25 percentage points on exam 1. It decreased to 2 percentage points on exam 2, and the gap was 9 percentage points on the final exam.

Study findings do not include the unmeasured influence of variables that can impact student performance, such as motivation. However, based on the performance of Lufaso’s students, the students in each group who attempted more Mastering Chemistry homework performed better on the comprehensive final exam than students in the same group who attempted fewer assignments. In addition, students in the LEI group who attempted more Mastering Chemistry homework narrowed the gap on each subsequent exam with those in the HEI group who attempted less homework. Further research is needed to test what the initial data seems to suggest is a relationship between (1) attempting Mastering Chemistry assignments and engaging in optional resources and (2) course performance.

The Student Experience
Students report that they like Mastering Chemistry and the opportunity to do its different types of activities. On the course evaluation, one student wrote, “The Mastering Chemistry homework online really did help me improve my work. Making it mandatory for students to do is a good decision. This way they are forced to learn what they wouldn’t do on their own leisure time.”

Conclusion
Since adopting Mastering Chemistry in 2006, Lufaso has continually redesigned his implementation with additional activities and assignments designed to address individual student needs and diverse skills and knowledge levels. “Mastering Chemistry has impacted my teaching in a positive way,” he says. “It enables me to obtain information about student learning more readily. I use that information to make changes to my lecture, in-class activities, notes, homework assignments, and exams.”

By better understanding student performance during the course, he is able to address issues as they arise, and then use the data to make informed decisions for future semesters.

Lufaso recommends that instructors who are starting to use Mastering Chemistry take advantage of the educator support to get trained, and use the implementation guide as a resource to plan the course around the instructor’s specific issues and goals. He explains that by designing the Mastering Chemistry course wisely and following best practices, the program can help instructors achieve the best results. Finally, he advises instructors to not immediately use every available feature, but to start with those that best address course goals. Evidence from Lufaso and his students suggests that thoughtful implementation of Mastering Chemistry has helped create a positive course experience for himself and his students.