Chapter 1: Introduction

This dissertation examines the relationship between “hands-on science”, a method of science instruction, and student achievement. We use the term “hands-on science” to include all hands-on activities carried out by students during their science class. The public policy debate over hands-on science in the U.S. goes back a century and primarily reflects a changing focus in theories and educational goals, and political influences rather than research findings of how hands-on science is related to student achievement. This dissertation attempts to fill this gap through a systematic examination of the relationship between the hands-on science students experience in the classroom and their science test scores in standardized multiple-choice tests and standardized performance tests.

Hands-on science has been on the rise from the 1970s as can be seen in a comparison of teacher surveys on hands-on science in 1977 and in 1996 shown in Table 1-1 below. The table shows large declines in the response “never or hardly ever”, large increases in the responses “1-2 times a month” and “1-2 times a week”, and smaller declines in the response “almost every day”. Overall, we see about a 30 - 40% rise in the percentage of teachers reporting at least weekly use of hands-on science.

Table 1-1: Teacher Reported Use of Hands-on Science

<table>
<thead>
<tr>
<th>Frequency of Hands-on Science</th>
<th>Grades 4-6 1977</th>
<th>Grade 4 1996</th>
<th>Grade 7-9 1977</th>
<th>Grade 8 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Every Day</td>
<td>12%</td>
<td>9%</td>
<td>24%</td>
<td>18%</td>
</tr>
<tr>
<td>1-2 Times a Week</td>
<td>27%</td>
<td>47%</td>
<td>38%</td>
<td>62%</td>
</tr>
<tr>
<td>1-2 Times a Month</td>
<td>27%</td>
<td>42%</td>
<td>17%</td>
<td>18%</td>
</tr>
<tr>
<td>Never/Hardly Ever</td>
<td>35%</td>
<td>3%</td>
<td>21%</td>
<td>2%</td>
</tr>
</tbody>
</table>

1 The data from the 1977 survey was collapsed from five to four categories and the percentages were recalculated to account for missing responses which were not reported in the 1996 data. Sources: Weiss 1978; Sullivan and Weiss 1999).
More recently, the centrality of hands-on science to instruction has come under debate for theoretical, practical and political reasons. Theoretically, there are concerns as to whether hands-on science is an optimal method to teach science and whether it best supports the goals of education. Two publicly funded national initiatives, Project 2061 of the American Association for the Advancement of Science and the National Science Education Standards of the National Research Council, are working to reorient the goal of science education toward scientific literacy for all students using an instructional method known as inquiry which includes a reduced role for hands-on science in instruction. Practically, hands-on science faces a challenge due to its relatively large time requirements per topic from concerns that students may learn more topics through other teaching methods. Politically, there are concerns whether hands-on science is of equal benefit to students of differing ability.

Past research has not provided satisfactory conclusions on any of these issues even the more fundamental one of the relationship of hands-on science to student achievement. Overall, small-scale experimental studies have not found a positive link between hands-on science and student test scores. Studies of the impact of curricula with a large hands-on science component show a positive link between curricula and higher test scores but it is not clear whether it is the hands-on component that is responsible for such a link. Findings based on national and international surveys have been inconsistent and inconclusive. Limitations in this work may contribute to the lack of conclusive findings. Sources of these limitations include: (1) a lack of control for factors that are linked to both hands-on science and achievement, (2) a lack of performance tests that
may better test the association of hands-on science to students’ achievement, and (3) a lack of attention to how different levels of student ability affect the relationship.

A goal of this dissertation is to address these limitations in previous research. Building on the literature, we specify three research questions. The first question asks whether there is a positive overall relationship between hands-on science and standardized test scores for both multiple choice and performance test scores. An overall assessment of the relationship between hands-on science and student achievement would inform educators and policy makers whether hands-on science should be emphasized. We use two types of standardized tests to measure achievement. Multiple-choice tests are widely used. Their broad content coverage helps us consider the concerns over narrowness of content coverage associated with hands-on science. Performance tests though less widely used help us address the concern that certain important skills are taught well using hands-on science but are better tested using performance rather than multiple choice tests. Evidence of a relationship would be stronger if found in both types of tests.

Our second question asks whether the relationship between hands-on science and achievement is stronger for performance tests than for multiple-choice tests. By examining the relative size of the relationship between hands-on science and multiple-choice tests vs. performance tests we can address the question whether performance tests are a better measure of the outcomes of hands-on science. These results will contribute to the current debate over the need for wider use of standardized performance tests.

Third, we ask whether the relationship between hands-on science and achievement differs by student ability. At a minimum, support for broad use of hands-on
science requires a positive relationship for at least one group of students and a neutral relationship with others. For example, if hands-on science benefits lower-ability students without hurting higher ability students, a policy emphasizing hands-on science will enhance educational equality without imposing a negative consequence on higher-ability students.

To address these three research questions we use two recent sources of data, the RAND 1994 Survey and the National Education Longitudinal Survey of 1988 (NELS:88) that compliment and supplement one another. The RAND data set surveyed 1400 8th graders and their teachers in Southern California. The strength of this study is that the students took both multiple choice and performance science tests allowing us to compare the relationship of hands-on science to each. NELS:88 surveyed approximately 25,000 students in 8th, 10th and 12th grades and their teachers. The sample is nationally representative to allow generalization to the whole population. Multiple-choice science test scores are available for the 8th, 10th and 12th grades, which allow us to examine the grade difference in the relationship between hands-on science and student achievement. NELS:88 includes broad information on teachers and students, allowing us to control for factors influencing both hands-on science and student achievement for an accurate assessment of the relationship between hands-on science and student achievement.

Our analysis will directly address the limitations of previous research. First, the analysis controls for variables linked to both hands-on science and student achievement, such as race, sex, ability, socioeconomic status, school environment, and course taking. Using a multivariate rather than bivariate method while controlling for these variables, we will be able to estimate the “true” net association of hands-on science and student
achievement. Second, exploiting the advantage of the RAND 1994 data that includes both multiple choice and performance test scores for the same students, we develop a statistical method to directly estimate the relative size of the impact of hands-on science on multiple-choice tests vs. performance tests of the same students. Third, we examine the relationship of hands-on science to student achievement for students of different ability levels and in different grades by including interaction terms between hands-on science and ability groups and by comparing the estimates for different grades. In addition, we undertake several sensitivity analyses to tests of the robustness of our findings.

The structure of the dissertation is as follows. Chapter 2 provides background on hands-on science including its formal definition, the continuum of instructional approaches for its use, the history of its promotion, and the current policy debate over its role in science education. Chapter 3 combines a review of the theoretical rationales for hands-on science’s link to student achievement with a review of the past research on this topic to develop hypotheses regarding our three research questions. In addition, the two data sets, RAND and NELS:88, used to test the hypotheses are briefly introduced. Chapter 4 presents the analysis that tests the hypotheses using the RAND data set, including measurement, model specification and interpretation of results. Chapter 5 does the same for the NELS:88. Chapter 6 summarizes the major findings from the two data sets, makes concluding remarks, offers policy implications, and discusses opportunities for further research.