# Opportunity to Learn Science in the Classroom: An Implemented Curriculum Perspective

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*This study is based on the work of a comprehensive Mathematics and Science Partnership (MSP) designed to stimulate curricular reform using an evidence-based model. The MSP uses the framework and instruments developed for the Third International Mathematics and Science Study. In the present report data on teachers' reported coverage of science topics were obtained from 1699 elementary and 373 middle school teachers in 53 school districts from two states in the US. Results indicate that there is extensive variation in the time allotted to science instruction at the district, school and classroom level. Thus, the science curriculum being experienced by the student not only varies by school district and school but also by classrooms within the same school. Such variability has an impact on what students learn in science and affects the depth of their understanding.*

**Keywords:** Implemented curriculum, Science, Content coverage

## Introduction

A seminal report from the National Academy of Science in the US (2005), *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academy of Science), underscored the urgency of investing in science and mathematics education. To "compete, prosper, and be secure in the global community of the 21st century", this investment was considered critical for the country. In his book *The World is Flat,* Friedman (2005) reiterated the same concerns: *"The truth is, we are in a crisis now…And this quiet crisis involves the steady erosion of America's scientific and engineering base, which has always been the source of American innovation and our rising standard of living".* Schmidt et al., (2001) in *Why Schools Matter* state:

> *Curriculum is at the very center of intentional learning in schools, specifying content and directing students in their efforts to understand mathematics and science…schools matter because the curriculum-learning opportunities they provide students have a profound impact on the mathematics and science students actually learn (p. xix).*

This study is based on data collected as a part of the PROM/SE project (Promoting Rigorous Outcomes in Mathematics and Science Education, NSF Cooperative Agreement EHR-0314866). The goal of this project is to stimulate systemic curriculum reform using an evidence-based model to promote change. It uses the framework and instruments of the Third International Mathematics and Science Study (TIMSS and TIMSS-R) to inform local curriculum reform (Schmidt & Cogan, 1996). In the PROM/SE project, the focus is on linking the intended (standards) with the implemented (teacher coverage of topics) and the attained (student performance on mathematics and science assessments) curriculum. In this paper teachers' reported content coverage of science topics is taken as evidence of the implemented science curriculum.

## Conceptual Framework

In PROM/SE, the theory regarding improvement of student achievement is as follows: we need to understand what students know, what is expected of students (standards), what teachers actually teach, and then make an effort to improve and align all three.

### *Three instantiations of curriculum*

The tri-partite model of curriculum that has been employed in many studies sponsored by the International Association for the Evaluation of Educational Achievement (IEA) since the First International Mathematics Study (1960s) (Travers & Westbury, 1989) and provides the conceptual basis for the instruments used in PROM/SE. The IEA tri-partite curriculum model defines curriculum at three different levels: the *Intended* – what a system intends students to study; the *Implemented* – topics taught in classrooms; and the *Attained* – students' demonstrated learning. The instruments used to gather evidence regarding three instantiations of the curriculum allows us to triangulate with respect to mathematics and science within a school district and enables teachers, curriculum and administrators to construct informed plans to improve student learning.

## Method

### *Participants*

Data were collected from 1,699 elementary and 373 middle school teachers were obtained between March, 2004 and May, 2005. In all 277 elementary schools and 144 middle schools from 53 school districts in two Midwestern states were represented by these teachers. Response rates varied from 90 percent for some school districts to about 55 percent for other districts.

### *Instrumentation*

Several of the instruments used in PROM/SE were initially used in TIMSS. The TIMSS Curriculum Frameworks were employed to measure the curriculum at the three different levels. As a result, comparisons could be made across each level in which curriculum was measured, i.e., nation, state and district (Intended), and classroom (Implemented).

In the study reported here, the *Teacher Content Goals Survey* was central. In its present version this survey was a web-administered[1] self-report measure[2] of the implemented curriculum. In addition to background information, teachers were asked to indicate the number of class periods they taught specific science topics. The exhaustive list of school topics used in the study was obtained from the TIMSS Curriculum Frameworks (Survey of Mathematics and Science Opportunities, 1992).

For each of the topics listed the teacher was asked to address the following close-ended question: To what extent did you teach each of the following topics in the science course indicated in No. 1 above during the 2003-2004 school year?

Teachers indicated the extent of topic coverage on the following scale representing class periods: 0; 1 or < 1; 2-5; 6-10; 11-15; > 15.

### *Index of content coverage*

Data on the number of periods over the year for each topic was first converted into percent teaching time and then into number of instructional days[3]. The 24 topics at the elementary level and 35 topics at the middle grade level were aggregated to broader categories such as biology, life science, earth science, physics and chemistry. A seven- point summary was obtained along with the 90 percent range.

For district level analysis, for each school, an average of instructional days on specific topic areas was calculated at each grade level. The difference between the highest and lowest averages provided the range of average days of instruction within districts. A low value for the range was indicative of small differences between schools within a district.

For school level analysis, the variability in topic coverage between classrooms within a single school at each grade level was calculated by determining classrooms with the largest and smallest number of instructional days. Once the range (difference) for each grade level within a school was determined, the entire distribution of ranges was used to create a seven-point summary and box plots.

Content standards of the four top achieving nations[4] were used to develop a model of coherent content coverage in science. According to Schmidt and Houang (2007) a coherent curriculum introduces topics and develops the ideas in a logical sequence. Individual topics are connected in a conceptual framework that is systematic both within and across grade levels. In the present study the intended science curriculum evidenced in TIMSS top achieving countries was used as an analytical framework to assess issues related to curricular coherence. Such curricula are characterized by the introduction and development of simple concepts before introduction and development of complex ones. When a concept is fully developed it is excluded from the curriculum to make time available for other important concepts. To maintain focus in early grades a relatively small number of concepts are selected for instruction. Figure 1 depicts intended topics common in e”75% of the high achieving countries. Scientists who collaborate in our project recognized the topic progression as coherent. The topics depicted in Figure 1 are part of the *intended curriculum* used for assessing the pattern of topic coverage by teachers. The shaded portion of the figure represents the intended topics at each grade level.

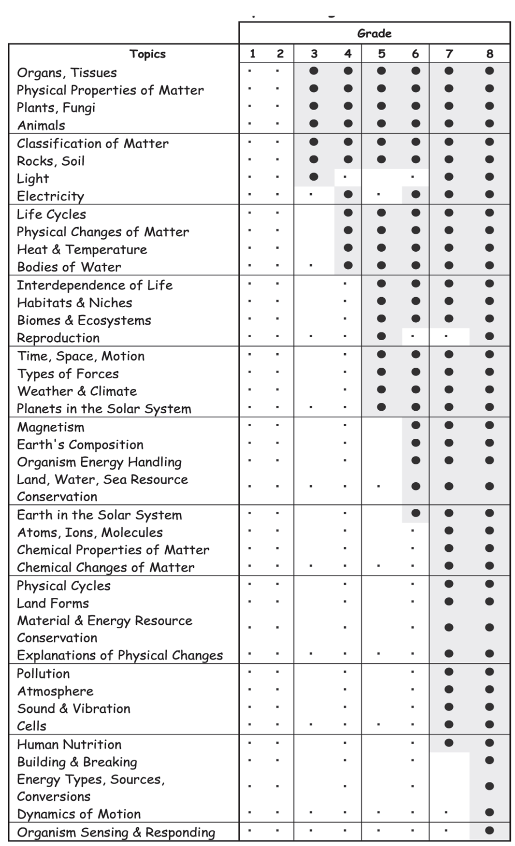


**Figure 1:** Science topics intended at each grade level by a majority of timss 1995 top-achieving countries

## Results

The results presented here focus on the group of topics covered by the top achieving TIMSS (1995) countries which we define as a *model of curricular coherence*, and the broad topic areas of life science, earth science and physical science. At each grade level, variation in content coverage between schools in the same school district and between classrooms within the same school is gauged. Due to page limits only a subset of the available results are presented in this paper.

### *Topics covered in the coherence model*

There was at least one district whose schools at the third and fifth grade levels had a difference of less than a day (on average) in instructional time. However, at these same grade levels there were districts where schools within the same district varied by about 107 and 94 instructional days at grades, respectively. In sixth and eighth grades, the largest difference in average instructional time between schools in the same district in covering topics in the coherence was 105 and 120 days, respectively (Figure 2).

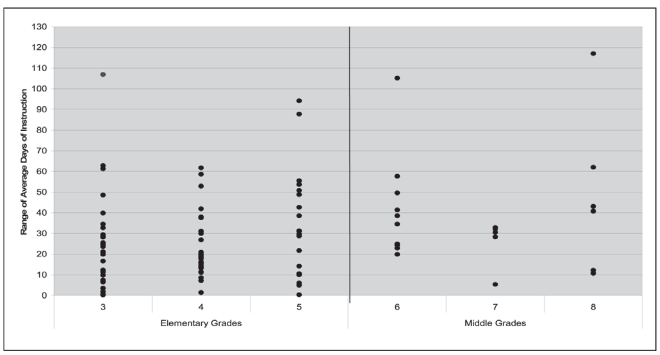


**Figure 2:** Range of average instructional days teachers spent in schools within districts on science topics in the coherence model

To highlight the impact of such variability in average instructional days we illustrate using data from a large urban area with a school district (District E), along with data from four adjoining ones in a geographical area that houses many diverse employers. Although employment opportunities may be sought in this district, the population often makes the choice of residing in neighbouring suburban areas (Districts A-D)

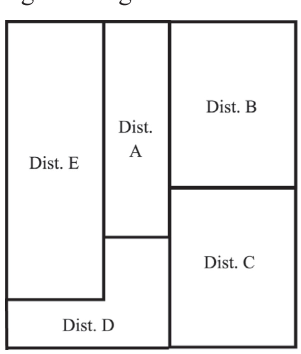


**Figure 3:** School districts neighbouring an urban district

and consequently, providing children in the family with educational opportunities in these districts. A simplistic representation of the districts is depicted in Figure 3.

In grades three and four, the range of average instructional days varied by about 30 days in Districts A - E. In grade five the range was considerably wider – whereas District A spent 86% of the instruction year (155 days) on topics in the model of coherence, District B devoted on average about 57 instructional days to the same topics.

### *Life science, earth science and physical science topics covered*

Schools in some districts do not differ in average instructional time allocated for life science, physical science or earth science. Other districts have schools whose average days of instruction might differ by 80 or more days. At the elementary grades the greatest spread of differences in time allocation on science topics between schools in the same district seems to occur in grades one and three.

In middle school, variability in average time spent on topics is not only affected by the grade level but also a function of the specific topics being covered. At the seventh grade, districts seem to have the greatest spread of ranges in average instructional days. For example, in coverage of earth science topics, within a particular district, two schools were so variable in their time allocations that the difference in instructional days devoted to earth science topics was almost 120 days. Thus, at one school within a school district, seventh grade students received 24 more weeks of instruction in earth science than students at another school in the same district.

The median difference in instructional days between two elementary grade classrooms in the same school on the topics ranged from 17 to 21 days for life science topics, 15 to 24 days for earth science topics and 9 to 17 days for topics related to physical science. There seemed to be little consensus regarding instructional time for content coverage in life science and earth science topics between teachers, who teach at the same grade level in the same schools. The middle marks the median, the lower and upper bounds of the bars are the 25th

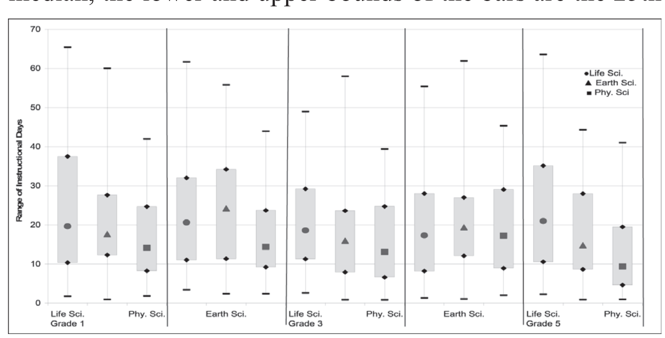


**Figure 4:** Box plot of range of instructional days elementary teachers spent on life, earth and physical science topics: classrooms within schools

and 75th percentile of ranges, respectively and the top and bottom hinges represent the 95th and 5th percentile of the range of instructional days, (Figures 4 & 5).

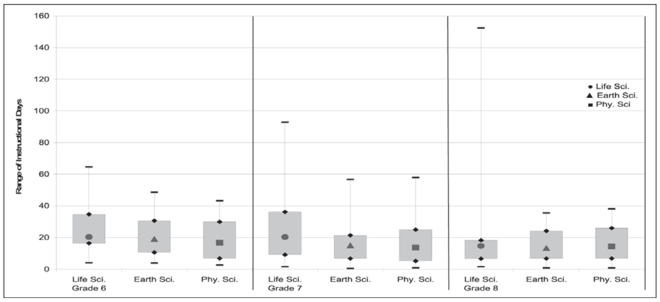


**Figure 5:** Box plot of range of instructional days middle school teachers spent on life, earth and physical science topics: classrooms within schools

In grades 6-8 the median differences between two classrooms in the same school is greatest for Life Science topics (Figure 5). In seventh and eighth grade there is at least one school where classrooms differ by 94 and 152 days, respectively. Such a large difference in the number of days devoted to life science topics suggests that students in two classrooms within the same school are experiencing distinctly different science curricula even though the parents of the students in the two classes may expect their children to have the same opportunities to learn science. This could adversely impact their preparation for the high school science curriculum.

## Conclusion

In the 53 districts studied, there is extensive variation in the time allocated to science instruction at district, school and classroom levels. This is true whether the definition of topics is empirically derived from the science curriculum of the TIMSS high achieving countries (model of coherence), or by the traditional categories of life science, earth science and physical science.

Wide variation in reported content coverage of of life science, earth science and physical science topics is also evident among schools within the same school district. School districts' role in the U.S. with reference to curriculum implementation is manifested in a variety of ways – textbook selection, articulation of instructional objectives, and assessments aligned with these objectives (Floden et al., 1988). Thus, the school districts may have articulated standards for teaching science but teachers in the school vary considerably in the implementation of these standards. When examinations for students are aligned with the standards then variation in implementation adversely affects student learning outcomes.

In our analysis of teachers' reported content coverage of science topics in the TIMSS high-achieving curriculum, it is clear that there is considerable variation. This variation seems to emerge in the early grades and persists (and widens) at the middle school level. Research indicates that students' understanding of content is facilitated and enhanced when topics are presented in a logical sequence so there is opportunity for students to connect disparate scientific ideas into coherent conceptual frameworks (Schmidt & Houang, 2007).

When there is variation in reported topic coverage at the classroom level, in the same grades, students within the same school may not be experiencing the same science curriculum. Teachers do not simply implement a prescribed curriculum but shape it (Craig, 2006). Teachers may differ in their content coverage due to individual differences in their understanding of science content, district/state level expectations, and school-level policies.

International assessments such as TIMSS and PISA have highlighted a decline in U.S. students' performance as they progress from elementary to higher grades. The variability in the implemented curriculum both in terms of topics covered and the depth of topic coverage may not only have an impact on students' opportunity to learn science topics in a focused and coherent way but also place them at a comparative disadvantage in the global workplace.

## Notes

[1] A paper-and-pencil version was also made available for those who had difficulty accessing the web.

[2] Self-reports have limitations but validation studies have found an acceptable level of agreement among self-reports of the implemented curriculum and direct observation.

[3] For purposes of this study 180 instructional days was used.

[4] The nations included were Singapore, Japan, Korea and the Czech Republic.

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