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OPPORTUNITY TO LEARN AUDIT: Elementary School Science

RENNIE CENTER
for Education Research & Policy

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About Rennie Center for Education Research & Policy

The Rennie Center's mission is to develop a public agenda that informs and promotes significant improvement of public education in Massachusetts. Our work is motivated by a vision of an education system that creates the opportunity to educate every child to be successful in life, citizenship, employment and life-long learning. Applying nonpartisan, independent research, journalism and civic engagement, the Rennie Center is creating a civil space to foster thoughtful public discourse to inform and shape effective policy. For more information about the Rennie Center and our current work, visit www.renniecenter.org, or call 617.354.0002.

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INTRODUCTION

Despite widespread media and public attention to the need for U.S. students to be globally competitive in science-related fields, remarkably little emphasis is placed on improving elementary science in U.S. public schools. Instead, policymakers have focused on improving science education in higher education, training high-quality secondary school teachers, and supporting more rigorous science courses in high schools. To be sure, all of these efforts are important. However, it is effective elementary science programs that provide the foundation for a sound K-12 education in science. Elementary school is the fundamental starting point for students, and as such, carries the potential for future scientists and scientifically-literate citizens to be developed and encouraged. Research has shown that early experiences in science can foster the development of children's problem-solving skills and motivate them toward a lifelong interest in science that empowers them to participate in an increasingly scientific and technological world.[1] Ultimately, engaging students in science from an early age holds the promise of creating a larger pool of students from which to build a pipeline toward careers in science and technology.

The federal No Child Left Behind (NCLB) legislation and state accountability systems have created external incentives to improve student achievement in science in addition to English language arts (ELA) and math. In 2010, Massachusetts will require all 10th graders to pass one of the science MCAS tests (in biology, physics, chemistry or technology/engineering) in order to receive a diploma. Yet, to date, schools have increasingly placed their emphasis on math and ELA, to the detriment of science. A recent report from the Center on Education Policy shows that since NCLB went into effect in 2002, 44% of districts nationwide have cut time on elementary school science, while 62% of school districts have increased the amount of time spent in elementary schools on English language arts and/or math.[2]

There is a substantial racial/ethnic achievement gap in the sciences, just as there is in math and ELA. English language learners, those who are African American or Hispanic, and students from low-income homes are all falling well below the standards for proficiency set by the state. In 2007, only 24% of low-income fifth grade students in Massachusetts scored proficient or advanced on the MCAS science test compared with the statewide average of 51%.[3] Additionally, 59% of White students scored Proficient/Advanced on the fifth grade science MCAS test, compared to only 20% of African American and 20% of Hispanic students.[4] Given that the state holds all students accountable for their performance in science, it is necessary to examine whether all students are receiving equitable opportunities to learn and succeed at science.

The purpose of this report is twofold: to analyze whether the students in high- and low-performing schools receive equitable opportunities to learn in science and, importantly, to profile the promising practices of schools that are beating the odds and succeeding at educating students to high levels in science.

In this report five top-performing elementary schools, five low-performing elementary schools and three schools that are outperforming expectations are analyzed, based on their performance on the fifth grade science MCAS test. Findings are based on self-reported survey responses from school principals. Building on these findings, recommendations have been made for district leaders and state policymakers.

Uncovering the gaps in opportunities to learn and analyzing how some schools succeed where others fail is crucial to formulating sound policy for improving science achievement. This report is the first in a two-part study that the Rennie Center is producing on Massachusetts students' opportunity to learn science. This report examines opportunities at the elementary (K-5) level. The second report, to be released in late Fall 2008, will highlight opportunities at the high school level (9-12). Differences in demographics between top- and low-performing schools exist, yet there are examples of schools with large populations of low-income, minority, and special education students that excel at science. This report seeks to identify concretely what top-performing schools do to support science instruction and to draw out considerations for policymakers at the district and state levels.

BACKGROUND AND CONTEXT

Massachusetts has a strong STEM (science, technology, engineering and mathematics) Pipeline initiative that spans K-12 education, higher education and workforce development.[5] One of the goals of the initiative is to expand student participation in high-quality science and math education. The strategy includes an ongoing statewide evaluation of Massachusetts' efforts to improve student learning, student persistence and teacher quality in the sciences and mathematics. Led by the Donahue Institute at the University of Massachusetts, the Massachusetts Statewide STEM Indicators Project (MASSIP) provides an analysis of combined efforts across the Commonwealth to increase the flow of students through a science, technology, engineering and mathematics educational pipeline. Annual indicator reports provide a basis for charting the Commonwealth's progress as a whole in promoting STEM education at all levels. Data from this project provide a state-level snapshot on a number of key input and outcome variables.

For example, the compiled indicators reveal the following:

- **The amount of science instruction students receive often lags far behind the amount of math and reading instruction they receive.** According to the results of the 2007 National Assessment of Educational Progress (NAEP), the median amount of time that Massachusetts fourth graders spent on English language arts was seven to ten hours. In math, the median time spent was five to seven hours each week. This represents an increase from 14% of schools that spent five to seven hours/week on math in 2005 to 32% of schools in 2007. Yet, in science, the median time spent per week was just two to three hours. Further, Massachusetts fourth grade students spent less time on science than the national average.[6]
- **Few students demonstrate grade-level proficiency in the sciences.** Slightly fewer than half (48%) of Massachusetts fifth graders scored proficient or advanced on the 2007 MCAS science exam. On the 2005 science NAEP, just 38% of Massachusetts fourth graders scored at the proficient or advanced levels.
- **Wider income-based disparities exist in science achievement than in math achievement.** On the 2005 NAEP exam, 46% of Massachusetts' low-income fourth graders scored in the "below basic" category in science while only 22% of these students scored "below basic" in math. Only 15% of low-income students scored proficient/advanced in science while 24% of these students scored proficient/advanced in math.
- **Massachusetts does poorly by its low-income and Hispanic students.** While the 2005 science NAEP assessment shows Massachusetts fourth graders among the top in the nation overall, low-income students in 16 states scored better than Massachusetts' low-income students. Hispanic students in 23 states scored better than Massachusetts' Hispanic students. That other states do better with low-income and Hispanic students suggests that students' demographics do not dictate their destiny and that it is possible to improve levels of science achievement for all students.

These data make clear that the Commonwealth must do much more to promote science learning among students at all grade levels. However, these data simply provide a composite portrait of the state as a whole. Because this prior research focuses exclusively on state-level indicators, it is not possible to explore the variation that exists between schools and districts in their approach to science instruction. The necessary next step for research on science education in Massachusetts involves collecting new data at the school and classroom levels.

METHODOLOGY

This study is the first of a two-part project and is focused on opportunities to learn science at the elementary school level. A second report, to be released in Fall 2008 will focus on science education in high schools across Massachusetts.

Two main questions lie at the foundation of this research:

- Do students in a diverse set of Massachusetts elementary schools receive equitable opportunities to learn and succeed at science?
- In schools that exceed predicted levels of achievement, what strategies and practices are central to their success?

Surveyed Schools

Thirteen schools were selected for this report. The ten top-performing and low-performing schools selected were identified by averaging the Composite Performance Index[7] for fifth grade science MCAS over two years, 2006 and 2007. Five elementary schools performing in the top 3% of all schools in the state and five elementary schools performing in the bottom 3% in the state were selected for this study. At the same time, three elementary schools were selected that are achieving better results than would be predicted from their demographics. These schools are included in this report as case studies that highlight best practices and lessons-learned.

As part of this study, structured interviews with principals were conducted in each of the thirteen schools based on specific survey questions. The following are some of the questions posed. *See Appendix A for the complete survey.*

- **Time on learning.** How much time do students spend in science? Does it systematically vary across grades 1 through 5? Is science offered over the course of the full school year, or for half the year?
- **Curriculum and Instruction**. Is the school using a recognized, hands-on curriculum? Did the teachers develop the curriculum themselves? Are the teachers using a curriculum generated primarily from a textbook?
- **Material resources.** What kinds of science equipment and supplies does the school have? What is the school's annual budget for science materials?
- **Staffing and professional development.** Does the school have an on-site science specialist? What science-focused professional development have teachers participated in over the past year?
- **Parent and community engagement.** Do parents advocate for and/or provide science opportunities at their child's school? If so, what are the results of this advocacy and what additional science-related opportunities have been provided?

None of the data collected for this study are currently collected or available for schools in the Commonwealth. In addition to profiling high-performing schools and revealing opportunity gaps, this project may help to clarify which indicators should be collected statewide on an annual basis.

DESCRIPTION OF SCHOOLS

This section describes the average demographic information and student performance data for the five top-performing schools, the five low-performing schools and the three case study schools compared with statewide averages. Of the thirteen schools selected, eight are K-5, three are K-6, and two are K-8 schools. The five districts that contain the top-performing schools in this study are all suburban communities within 25 miles of Boston. The three districts within which the low-performing schools are located are large urban centers.

Demographic Information

Table 1 below shows the average demographic information for the five top-performing, five low-performing and three case study schools in this study. On average, low-performing schools were more diverse, with much higher percentages of African American and Hispanic students. Low-performers also had significantly larger populations of English language learners and special education students. The average mobility rate for top-performing schools (only three of which collect this data) was less than 1%, while the average for low-performing schools was 24%. Finally, low-performing schools had an average percentage of low-income students twenty-two times that of top-performing schools.

Without question, large disparities in demographics exist between the top-performing schools and low-performing schools. Yet, there are schools that are beating these odds. On pages 10-14 of this report, three such schools are highlighted. All of these schools are located in large urban districts, have diverse student populations, and have high percentages of low-income students – yet each school is ensuring that students reach high levels of achievement in science.

Student Performance

For this study, student performance was analyzed using an average of fifth grade Composite Performance Indexes for 2006 and 2007. Table 2 shows the average performance levels of low-performing, top-performing and case study schools in science, English language arts, and math.

Table 1. School Demographic Information

	Enroll.	African American	Asian	Hispanic	White	Other/ Multi-Racial	English Language Learners	Special Education	Low-Income
Low-Performing Schools (5)	419	24%	3%	64%	7%	1%	27%	32%	87%
Top-Performing Schools (5)	479	3%	18%	2%	76%	1%	4%	13%	4%
Case Study Schools (3)	222	19%	8%	27%	40%	6%	10%	23%	63%
State Average		8%	5%	14%	71%	2%	6%	17%	30%

Table 2. Average Composite Performance Index Scores

	Science	ELA	Math
Low Performers	40	56	41
Top Performers	96	97	93
Case Study Schools	88	89	86
State Average	79	85	76

THEMES ACROSS THE SCHOOLS

This section describes findings from the five top-performing and five low-performing schools that participated in this study, based on ten interviews of principals. The findings are categorized in six main areas: 1) time on learning, 2) staffing and professional development, 3) curriculum and instruction, 4) material resources, 5) enrichment opportunities and 6) parent and community engagement.

1. Time on Learning

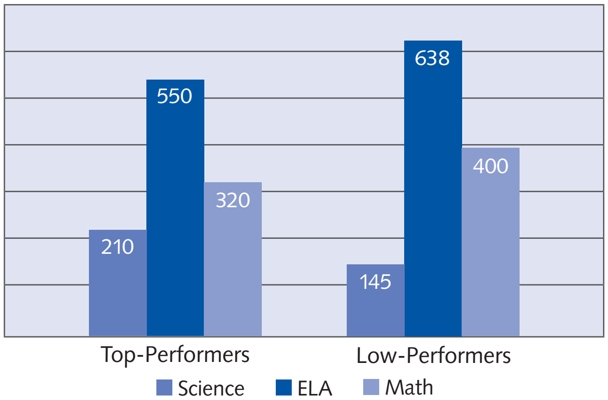
According to self-reports by principals, and consistent with previous national and state-level findings,[8] all of the schools in this study (both top- and low-performers) are spending significantly more time on English language arts and math than on science. This was especially the case in low-performing schools interviewed for this study, which are spending significant portions of the school day in expanded literacy and math blocks. All of the schools surveyed–both top- and low-performers–reported spending at least 90 minutes on English language arts (450 minutes per week) and 60 minutes on math each day (300 minutes per week). One low-performing school dedicated 165 minutes per day (825 minutes per week) for literacy instruction and 90 minutes per day (450 minutes per week) for math at every grade level, K-5. Two of the low-performing schools have expanded their school day – one by one hour and one by nearly two hours – and both have chosen to use that time solely to increase the amount of instruction in math and English language arts.

To date, the state and federal mandates emphasize ELA and math. As a result, low-performing schools are under extraordinary pressure to improve their students' test scores in math and ELA (not science) or face corrective action that includes the possibility of state takeover or removal of the principal. Given this context, it is not surprising that four of five principals of low-performing schools explained that science is currently not their primary focus; instead they are chiefly focused on improving their students' scores in English language arts and math. Predictably, most principals of low-performing schools mentioned accountability pressures to increase scores in math and English language arts, but did not describe this same pressure to increase scores in science. One principal of a low-performing school leaves the amount of time spent on teaching science to the teachers' discretion, stating, "There is only so much I can ask of my teachers." Another principal of a low-performing school reported that, "If something has to go, I'd rather it be science than math or ELA." By contrast, one principal of a low-performing school was committed to spending time on science, stating, "As long as I am principal, science will always be a priority. It's the only time that some of our special education and English language learners really engage" because of the focus on activity-based instruction in science. This principal reported the highest amount of time per week for science instruction among low-performing schools, with fifth graders at her school receiving 250 minutes per week of instruction in science as compared with an average for low-performing schools of 145 minutes.

Most school principals of both top- and low-performing schools reported that they teach science all year long. However, one principal of a top-performing school reported that teachers at her school taught science for half the year, teaching social studies in the fall and science in the spring semester.

There are notable differences in the amount of time spent on science between top-performing schools and low-performing schools. The average top-performing school in this study spends 65 more minutes per week on science instruction than the average low-performing school.

Chart 1: Average Minutes per Week Spent on Fifth Grade Science, ELA and Math in Top- and Low-Performing Schools



2. Staffing and Professional Development

Before describing the findings in staffing and professional development, it is important to point out that few indicators of teacher quality for teachers of elementary science exist. Elementary teachers are usually certified under a general education certificate, which does not provide specific information about their levels of expertise in science. Thus, this section provides analysis of the amount of staffing for and support of science instruction, but does not analyze the quality of this staffing and support.

There were a few key differences between top-performers and low-performers in their staffing and the professional development provided for teachers. For example, top-performing schools were more likely to report that they had regular access to onsite professional development and mentoring from district science coordinators. At the same time, low-performing schools had significantly more common planning time than top-performing schools (though this time was not specifically designated for science). However, there were also characteristics that were consistent among these groups. There was no marked difference in the average class size for low-performing schools (21 students) as compared with high-performing schools (22 students). All schools had access to district-level coordinators, and mandated professional development in science was rare in both top- and low-performing schools.

All the participating schools have district-level science coordinators. These coordinators are primarily responsible for ensuring that districtwide curriculum is aligned to standards, hands-on materials are distributed to schools in a timely fashion and science kits are complete. In most cases, district science coordinators also coordinate science-related professional development for teachers. In three of five of the top-performing schools and one of five of the low-performing schools, district science coordinators visit schools regularly to model lessons and provide professional development to teachers (especially new teachers). In two of the top-performing schools, the district science coordinator also helps to mentor new elementary teachers in science.

One of the low-performing schools has a school-based, part-time science coordinator who focuses on working with teachers. At this school, teacher turnover has been high and the science coordinator has been critical in helping new teachers with science instruction through modeling lessons, observing new teachers and debriefing with them afterwards. While none of the other schools in this study had school-based science coordinators, several schools found creative ways to use staff to maximize their science instruction. In three of the five top-performing schools, one fifth grade teacher is assigned to teach science for all fifth grade students, while other grade level teachers teach other subject areas. One principal described, "This is a great way to increase teacher accountability–and ownership," since just one teacher is responsible for all of the fifth grade science scores. One of the low-performing schools utilized the school's part-time technology teacher to assist with science instruction through the planning and modeling of science lessons in all classrooms.

While harder to quantify, principals in four of the five top-performing schools described having several teachers with a particular interest in or focus on science. None of the principals of the low-performing schools mentioned having teachers with a special interest in science. In one top-performing school, the fifth grade teacher who was designated as the grade-level science teacher for the entire fifth grade stated, "If I could teach the entire curriculum through science, I would." In another top-performing school, it was the principal who had a special interest in science. This principal is an adjunct university faculty member who teaches graduate courses in science for elementary school teachers.

The average amount of common planning time for low-performing schools was 123 minutes per week as compared with an average of 36 minutes for top-performers. The range of common planning time spanned from one top-performing school that did not provide any common planning time for teachers, to one low-performing school (with an expanded school day) that provided three hours of common planning time to teachers each week. It is important to note that two of the low-performing schools have expanded school days, affording them more flexibility to provide common planning time. Both of the expanded learning time schools are in their first year of implementation, so it is possible that it is too soon to tell the impact of common planning time on student performance.

Almost all of the schools surveyed lacked mandated science-specific professional development opportunities for teachers. Just two of the top-performing schools mandated science-related professional development. One school had three days of district-mandated science professional development in school year 2006-2007 for all elementary teachers in the district. Another school used one of its mandated school-based professional development days to have all teachers review and revise the school's science curriculum. This school also launched a science book club for teachers to voluntarily attend after school. One of the low-performing schools also mandated professional development in science for fifth grade teachers. All of the districts within which the 13 schools in this study were situated provided science-related professional development opportunities for teachers to attend on a voluntary basis. Top-performing schools were more likely to report that they were able to offer to pay for teachers to attend these voluntary opportunities and to provide substitute coverage for teachers when it was needed.

3. Curriculum and Instruction

There were noticeable differences between top-performing and low-performing schools in curriculum and instruction. While all of the schools in this study–both top- and low-performers–had district-based curricula aligned to state frameworks, they adhered to these curricula to varying degrees. Three of the five low-performing schools reported that they did not (or were not able to) strictly adhere to the district's science curriculum. Two of the principals of low-performing schools admitted that science instruction was often squeezed out by math and English language arts and one described that only half of his teachers had been trained in teaching the district's science curriculum. All of the low-performing districts provided grade-level pacing guides in addition to the curriculum.

All of the participating schools used hands-on activity kits/modules to some degree and most described using an inquiry-based approach to science instruction. The most commonly mentioned curriculum, by both top-performers and low-performers, was the Full Option Science System (FOSS) program, a research-based science curriculum for grades K-8 developed at the Lawrence Hall of Science, University of California at Berkeley. All of the top-performing schools described a process, either at the school or district level, for regular re-design and improvement of their science curriculum. Two top-performing schools had recently updated their science kits to adhere to the Understanding by Design (UbD) framework, which focuses on fostering deep understanding of content.[9] One feature of this framework is "backward design" or planning lessons by starting with the specific goal for what students should learn.

One principal of a low-performing school reported that in order to ensure that hands-on science kits were properly used, his district required teachers to be trained in using the kits before they were approved to receive kits for their classrooms. Only about half of the teachers in his school had completed the science kit training and were currently using the kits in their classrooms. In this district, the kits were the main component of the science curriculum, therefore, without access to the kits, the untrained teachers either did not teach science or developed their own curriculum. The principal of another low-performing school sent his fifth grade teachers to be trained in teaching the district's mandated science curriculum last summer, but after observing the teachers, found that most were not fully implementing the training and instead were using traditional, direct instruction to teach science. The principal has now mandated that the fifth grade teachers receive additional professional development in science instruction monthly at the school, as well as attend off-site workshops.

All of the five top-performing schools reported an emphasis on integrating science with other subject areas–especially in English language arts, through connections with non-fiction literature. Several schools mentioned that they were in the process of building libraries of non-fiction science-related books at various reading levels. Only one low-performing school reported a focus on integrating science into other content areas.

The provision of MCAS science review for fifth grade students was described by all of the top-performing schools. Four of five of the top-performing schools incorporated into their curriculum explicit opportunities for fifth grade students to review the entire elementary science curriculum upon which the MCAS test is based. By comparison, only one of the low-performing schools mentioned the provision of a comprehensive science review for fifth grade students, in preparation for the MCAS.

MCAS Review Strategy

One top-performing school helps fifth grade students review for the science MCAS by inviting students from the lower grades to present what they have learned from their science lessons to fifth graders. This provides review for fifth graders, while deepening the understanding of the younger students, and empowering them as teachers.

4. Material Resources

Just one of the top-performing schools had a science lab, a separate classroom dedicated to teaching science. In this lab, shelves were stacked neatly from floor to ceiling with science kits aligned to the curriculum at each grade level and extra consumable materials–all of which had been compiled and organized over the summer by parent volunteers. None of the low-performing schools had lab facilities.

All of the low-performing schools used science kits that were aligned to their districts' curricula and transferred from school to school by the district. In contrast, all of the top-performing schools had science kits that were housed at each of their schools. In four of the top-performing schools, there was a central (and organized) storage space for science materials from which all teachers could draw and which parent volunteers kept orderly and restocked either throughout the school year or over the summer. Just one of the low-performing schools had a well-stocked, school-based repository of science materials.

All of the schools in this study had computer labs with at least fifteen computers. Most of the schools, whether low- or high-performing, had at least two student computers in each classroom. Four of the five top-performing schools described the ways in which they used technology to teach science, while only one principal of a low-performing school described science-related uses of technology. One of the top-performing schools had a Mimio, a portable device that attaches to any whiteboard, connects to a computer and a projector, and allows teachers to display and control desktop applications and documents directly from the board. This was transferred from classroom to classroom and, combined with web streaming, used to take students on virtual fieldtrips and to demonstrate experiments that were not feasible to conduct with elementary students. This school also used a document camera to display demonstrations such as the parts of insects or the parts of a flower.

None of the low-performing schools had a school-based budget for science materials, while four of the five top-performing schools had line items in their budgets designated for science materials. The average school budget for science among top-performers was $3,000.

5. Enrichment Opportunities

None of the low-performing schools reported having access to natural resources on the school site, while three of the five top-performing schools had on-site nature trails. However, all of the schools–both top- and low-performers–reported providing science-related enrichment opportunities for their students through school-based presentations or field trips.

All of the top-performing schools provided field trips to area science museums, local arboretums and nature preserves. Three of the five low-performing schools provided field trips to area science museums and these schools have also developed partnerships with community organizations and universities. One low-performing school established a partnership with CityYear and Earthworks, a non-profit organization that has developed an Outdoor Classrooms Program to provide hands-on, environmental education to public school children by establishing and using schoolyard orchards (working with local groups to plant, maintain, and harvest fruit- and nut-bearing trees, shrubs, and vines on urban land as learning space). The majority of top-performing and low-performing schools took advantage of access to local parks and nature preserves to which they would transport students for day-long fieldtrips. One low-performing school was recently awarded a grant from a local foundation to begin a robotics program in school year 2008-2009.

Naturalist Program

One top-performing school is located on wetland property with a nature trail that abuts the town's arboretum. In order to best make use of these natural resources, the school developed a Naturalist Program. Through work with a naturalist, teachers developed an environmental education program that is specifically tied to the district's science curriculum. Parents, trained as Environmental Aides, lead the program, which is funded by the school's PTO. Working with the town's Natural Resources Office and the Community Preservation Committee, the school has developed a network of instructional nature trails that surround the building. Fifth grade students, whose curriculum includes forest ecosystems, are the custodians of the nature trail, taking care of the trail and serving as trail guides for younger students. While replication of this program would be difficult or impossible in most urban elementary schools, these schools may instead consider developing partnerships (like the Outdoor Classrooms Program mentioned above) that can provide urban students with opportunities to engage in science in a real-world context.

6. Parent and Community Engagement

Large disparities exist between parent and community engagement at the low-performing and top-performing schools. Parents were much more involved in the top-performing schools than in low-performing schools. None of the low-performing schools reported any science-related support, activities or resources provided by parents, while all of the top-performing schools listed examples of parent support–in most cases, several examples. Parent support in top-performing schools ranged from parents organizing materials and re-stocking science kits, to an annual schoolwide parent-initiated and led science fair.

All of the top-performing schools had active Parent-Teacher Organizations (PTO). The PTOs in all of these schools provided additional financial resources to purchase science equipment, like microscopes as well as other science-related resources. In one top-performing school, each grade level had its own set of microscopes, which were provided by PTO funds. PTOs also assisted with paying for and organizing science-related enrichment opportunities like field trips to museums, arboretums, the ocean and school visits from presenters like the Mad Scientist and Mr. Magnet. In three of the five top-performing schools, PTOs also provided mini-grants for professional development opportunities for teachers, which in some cases were science-related.

In addition to active PTOs, two of the top-performing schools reported having town-based education foundations that provided grants for teachers' professional development. In one community, the education foundation also supported the district's participation in a robotics program.

Finally, all of the top-performing schools mentioned having a highly educated parent community. Four of the five top-performing schools reported having a large population of parents with science backgrounds. One top-performing principal described that a large number of her school's parents were engineers, many of whom came to the U.S. from other countries to take science- and technology-related jobs. Another teacher at a top-performing school described parents' education levels at her school, stating, "Almost all of our parents have degrees, most have Master's degrees and many have Ph.D.s."

Mentor Night

One top-performing school organizes an annual "mentor night." Each third, fourth, and fifth grade student in the school writes an essay that describes what they want to be when they grow up or the profession about which they are curious. The Parent-Teacher Organization then matches students with mentors (adults in these professions) who meet with students three times throughout the year. At Mentor Night, students present what they have learned about their mentor's profession. While not specifically targeted to science, many of the students select mentors with science-related careers like meteorologists, engineers, and doctors. In this way, Mentor Night provides a real-world context for learning science.

CASE STUDIES

This section describes three schools, all located in urban districts with large populations of low-income students, whose students are achieving at high levels in science. Case studies were selected based on two criteria: schools whose 5th grade science MCAS performance is in the top 10% of the state that also have a low-income student population over 50%.

Case study schools stand out in terms of their clear focus on science. These schools are using the district science curriculum and working to integrate science, English language arts and math. The schools profiled here all have ample access to science materials and provide additional opportunities for science enrichment outside the classroom. Moreover, all of the case study schools have been creative about establishing additional staff positions to support science instruction, even when their districts did not formally provide for these positions.

CASE STUDY 1:

Arthur Talmadge Elementary School, Springfield, MA

Located along a major route in Springfield, the Arthur Talmadge Elementary School is surrounded by a large playground, wooded lot and a neighborhood of single-family homes. Talmadge is home to 271 students from kindergarten through fifth grade. With its diverse population and high percentage of low-income students, Talmadge is doing what other schools have not–proving that all students can achieve at high levels. In 2008, 91% of Talmadge students, 79% of whom are classified as low-income, passed (at the advanced, proficient and needs improvement levels) the 5th grade science MCAS test.

Table 3. Student Demographic Information for Talmadge Elementary

African American	28%
Asian	2%
Hispanic	32%
White	29%
Other/Multi-Racial	9%
English Language Learners	4%
Special Education	15%
Low-Income	79%
Mobility Rate	5%

Talmadge has made science a clear priority for students and teachers through the provision of science materials, technology, classroom space, and especially, a dedicated science resource teacher. Additionally, all students from kindergarten through fifth grade receive four hours and ten minutes of science instruction each week throughout the whole school year.

Curriculum and Instruction

The Springfield Public Schools developed a districtwide K-5 science curriculum and pacing guide aligned to Massachusetts science frameworks that covers September through June and includes one mid-term and one final exam for each grade level. *See Appendix B for Springfield's Elementary Science Curriculum Pacing Guide.* Talmadge School uses this curriculum guide schoolwide. Teachers at Talmadge employ a range of curriculum materials that include teacher-developed science activity kits and published science texts and materials. The science kits are the heart of the curriculum, resulting in science instruction that is hands-on and activity-based. The science resource teacher and classroom teachers use science kits that include experiments and activities to foster an inquiry-based approach to learning science. Science is also integrated into lessons in other subject areas throughout each grade level. Both the art and physical education teachers often weave science into their instruction.

Staffing and Professional Development

Talmadge has also made a commitment to science through its staffing. The school has a full-time resource teacher who focuses exclusively on science.

All students receive instruction from this dedicated science resource teacher, except for one science unit, which is taught by their regular classroom teacher. Talmadge's science resource teacher often collaborates with classroom teachers on the planning and teaching of this one unit. The district, too, provides an elementary science coordinator who is available to come into schools to teach lessons upon request and who oversees the district's elementary science-related professional development. Talmadge's long-time science resource teacher became the district science coordinator in school year 2007-2008 and was replaced by a new science resource teacher with many years of experience teaching elementary science at another Springfield elementary school.

Facilities and Materials

Talmadge's focus on science is also evidenced by its science lab. The science resource teacher is based in a science lab that is equipped with lab tables, a computer and a Smartboard with online streaming capability, which the science resource teacher reported that she used everyday to bring science concepts to life for all students in grades K-5. The Smartboard allows her to stream video for her students and to switch quickly between video clips and demonstrations. The science resource teacher is also able to save previous lessons, including students' comments, and refer back to those lessons to demonstrate how student thinking has evolved as the students progressed from lesson to lesson. In addition to the Smartboard, the school has its own supply of microscopes, scales and other equipment necessary for conducting hands-on experiments.

Enrichment Opportunities

Talmadge students have access to a nature trail and woodland community behind the school. A professor from Springfield College designed a course to accompany the nature trail that is now used by students. Staff at Talmadge also take advantage of various resources in the community including an annual fifth grade trip to the Springfield Science Museum. Each year, students also travel to the Environmental Center for Our Schools (ECOS) at Forest Park, a hands-on environmental science program in which each 4th–7th grade Springfield student and teacher spends two school days at the Clifford A. Phaneuf Environmental Center in Forest Park.

Science Expo: MCAS Review Made Fun

Talmadge fifth graders participate in a Science Expo that takes place in the school's gymnasium in May. The Science Expo consists of a series of activity stations designed to help students review a range of science concepts in preparation for MCAS. Students are provided with a worksheet that asks them to collect information from each activity and respond to questions. Students spend ten minutes at each station working on a hands-on activity and answering specific questions. The range of activity stations mirrors the areas tested by the science MCAS and provides students with a fun way to review for the test.

Parent and Community Support

With funding provided by the PTO, Talmadge runs an Elementary Science Olympiad program for grades K-5 which takes place during the school day. Students develop science investigations on various topic areas and present their findings to other grades, becoming teachers for one another. The PTO also funds science-related field trips and a science-related after-school program called "Mad Science," which provides one-hour science programs focused on a particular area of science, such as rocketry, magnets, polymers and the science of toys.

CASE STUDY 2:

Mary Lyon K-8 School, Boston, MA

Nestled in a Brighton neighborhood of multi-family homes, the Mary Lyon K-8 School is a small, two-story brick building that is home to 114 students in grades K-8. A full inclusion school with 41% of the school population identified as special education students, Mary Lyon has just one class per grade, small class sizes and a favorable teacher:student ratio of 1:6. Mary Lyon's faculty has been extraordinarily effective in serving students with special needs. In 2007, 99% of Mary Lyon students passed the 5th grade science MCAS; 14% scored advanced and 71% at the proficient level.

Table 4. Student Demographic Information for Mary Lyon School

African American	22%
Asian	10%
Hispanic	26%
White	46%
Other/Multi-Racial	9%
English Language Learners	3%
Special Education	41%
Low-Income	56%
Mobility Rate	7%

Curriculum and Instruction

The Boston Public Schools (BPS) has a districtwide elementary science curriculum aligned to Massachusetts science frameworks. Mary Lyon teachers use this curriculum guide schoolwide along with science kits that are provided by the district. The principal stressed her faculty's fidelity to the implementation of the science kits: "We do it the way it's supposed to be done."

Teachers at Mary Lyon focus on writing across the curriculum and they have built in a writing component to the science kits. All students keep science notebooks in which they document and reflect on their learning. Mary Lyon is also working to incorporate non-fiction science reading into the curriculum by identifying science books at various reading levels that are tied to the district's science curriculum at each grade level.

Several years ago, a small group of Mary Lyon teachers developed a test-prep program based on the work of Lucy Calkins[11] that was designed to provide students with strategies for taking multiple choice tests. The Boston Plan for Excellence videotaped the teachers and distributed the videotapes districtwide. According to the principal, this program has given students more confidence in taking MCAS and she believes this has contributed to increases in their scores.

Staffing and Professional Development

Mary Lyon has one teacher per grade and because of the high percentage of special education students, there is also one paraprofessional at each grade level. The small class size at the Mary Lyon allows for more individualized attention to student learning in science as well as across the rest of the subject areas.

Mary Lyon's principal has also been creative in finding ways to enrich instruction in science. The school has a physical education teacher assigned three days a week, but Mary Lyon has no gymnasium in which to teach physical education. Since the physical education teacher has a degree in engineering and a background in science, he serves as a part-time physical education/science resource teacher–especially in the winter months, when it is too cold to hold gym class outside. The physical education teacher also provides mentoring to new teachers, often co-teaching or serving as the lead teacher on science lessons for beginning teachers.

The Boston Public Schools is working with the Massachusetts Institute of Technology (MIT) to develop a new professional development opportunity in science. For the past five years, BPS has used the Collaborative Coaching and Learning (CCL) model to provide on-site, job-embedded professional development for teachers in math and English language arts. Mary Lyon is one of the first cohort of schools to adapt the CCL model to science. Using the CCL model, teachers work together on a grade-level team to plan a science lesson, then each team member teaches this lesson while the other team members and a science coach observe. After each lesson, the team meets and reflects on the lesson together, discussing what students learned, where they got stuck and what could be improved in the next lesson.

Mary Lyon also has a full-time art teacher who often reinforces science concepts with her art lessons and projects. For example, students build the solar system to scale in fourth grade and first graders make their own insects.

Facilities

Mary Lyon is located in a small school building with no space for a science lab and no resource room or storage space for science materials. The school has one computer lab with 18 computers. Using school funds, Mary Lyon purchased its own microscopes, which are primarily used by grades six through eight, but are available for use in the earlier grades.

Enrichment Opportunities

Mary Lyon students are within walking distance of the Charles River and can also walk to a nearby pond for science investigations and experiments. Students also participate in an annual trip to the Museum of Science. Last year, Mary Lyon created a science club that meets two days a week for 90 minutes. While the club largely targets students in grades six through eight, students in earlier grades with a particular interest in science are welcome to participate. One day each week the club conducts a science experiment or exploration and the other day students prepare for the district's science fair.

Parent and Community Support

Mary Lyon parents are generally working parents and do not provide any science-related support or resources to the school. In addition, Mary Lyon does not have community-based partnerships that relate to science.

Electronic Portfolios

All students at Mary Lyon create electronic portfolios that contain assignments and capstone projects that reflect their learning over time, from one grade level to the next. Teachers use these portfolios to document and assess students' learning and growth over time. However, these portfolios are also helpful to students as tools in reviewing previous science lessons and projects in preparation for the fifth grade MCAS.

CASE STUDY 3:

Lake View Elementary School, Worcester, MA

Lake View Elementary School is home to 280 students from kindergarten through sixth grade, located in a small Worcester neighborhood of single family homes. Lake View is another example of a school that is outperforming expectations. In 2007, 94% of Lake View students passed the 5th grade science MCAS test and 61% scored in the advanced or proficient range.

In order to support science instruction, Lake View elementary places a priority on integrating science, math, English language arts, physical education and art. Students receive three hours and 45 minutes of science instruction each week throughout the whole school year.

Table 5. Student Demographic Information for Lake View Elementary

African American	8%
Asian	11%
Hispanic	23%
White	50%
Other/Multi-Racial	1%
English Language Learners	24%
Special Education	13%
Low-Income	54%

Curriculum and Instruction

Six years ago, a team of teachers from Worcester were awarded a grant to work with professors from the University of Massachusetts to develop a science curriculum for the district's North Quadrant that was inquiry-based, hands-on and aligned to Massachusetts science frameworks. Through this project, teachers developed the K-6 science curriculum, created the hands-on kits that would be used to teach it and provided professional development to teachers throughout the district.

According to staff at Lake View, science instruction is not confined to the allotted 45 minutes each day. Teachers at all grade levels work to integrate science into other subjects. Teachers integrate science into their literacy lessons focused on non-fiction. Across grade levels, teachers work to link science vocabulary with students' real-world experiences, whether at recess, in the lunch room, or in the classroom.

The inquiry-based approach to teaching science permeates the school; teachers at each grade level ask questions about their students' surroundings and encourage students to explore and test their thinking through scientific reasoning. Teachers describe seeking and creating teachable moments when students' natural curiosity about nature or physics can spark an exploration of science concepts. This approach relies on teachers who are focused on and knowledgeable about science, constantly looking for opportunities to teach science when situations arise that relate science to students lives and make science concepts meaningful.

Staffing and Professional Development

Teachers at Lake View are particularly focused on teaching science and several have a particular interest in it. These teachers combine a love of science with high expectations for all students. Lake View has a part-time school-based science coordinator, who is also the assistant principal and a classroom teacher. Since she has so many other responsibilities, the science coordinator is only responsible for making sure materials and supplies are available for all of the teachers; she does not provide professional development or teach science lessons in classrooms other than her own. Worcester also has a district elementary science liaison available to provide professional development at the request of schools.

Holy Cross has provided Worcester elementary teachers with free access to a three-week graduate course in science. Clark University also offers free courses to teachers in the Worcester Public Schools, who are eligible to take up to four free courses. Lake View periodically mandates professional development focused on science for teachers, based on principal observations and student performance.

Facilities and Materials

Lake View does not have a science lab, but it does have lab equipment. The school has one class set of microscopes and assorted petri dishes, beakers, graduated cylinders and magnifying glasses that all teachers in the school share. There is one computer lab with 15 computers and five to six computers in each classroom.

Parent and Community Support

Lake View has support from an active PTO. Parents help to provide additional science-related materials, such as microscopes, and organize science materials at the school. The school has a garden that parents have planted and helped to maintain, working with students and classroom teachers.

SUMMARY OF THEMES

This study represents a first step in determining which factors contribute to success in science at the elementary level. It is a small-scale study (13 elementary schools) and the data presented are based on self-reports from principals, who may have varying degrees of knowledge about the amount and type of science instruction that takes place in their classrooms. In order to get a truer picture of the disparities in science instruction, much additional research is needed–particularly at the classroom level. However, these data do present clear gaps in the opportunities to learn science presented at top-performing and low-performing schools. The following is a description of **greater opportunities** to learn science that are present in top-performing schools, compared to low-performing schools:

- **More time on science.** Top-performing schools averaged 65 more minutes per week of science instruction than low-performers.
- **School leadership focused on science.** In most of the top-performing, but few of the low-performing schools, leaders valued and prioritized science.
- **Regularly scheduled support from district science coordinators.** Top-performing schools were more likely to report having regular access to district science coordinators who were scheduled to spend time in their schools each week, co-teaching lessons and providing on-site professional development for teachers. While low-performers also had access to district science coordinators, these coordinators were available as needed, so that low-performing schools had to take the initiative to request a visit from the coordinator.
- **Teachers who specialize in science.** Top-performers were more likely to have, or to create, roles for teachers with specialized knowledge of science. In fact, three of the five top-performing schools have fifth grade teachers who are solely responsible for teaching science to all the fifth graders in their schools.
- **Professional development.** While there was a paucity of science-specific professional development required in all the schools in this study, school leaders in top-performing schools were more likely to mandate or encourage science-related professional development for their teachers and to provide stipends and substitutes for teachers who attended voluntary professional development.
- **Science materials housed at their schools.** Top-performing schools had constant access to science materials at their schools, as compared with low-performers who used science materials for an allotted period of time and then were required to send them back to the district. The increased access to materials provided teachers at top-performing schools with flexibility to be responsive to students' needs and interests in the length of time that they could spend on a particular science concept.
- **School budgets for science.** Most of the top-performing schools had budgets for science materials that allowed them to purchase consumable materials, equipment and other resources for their schools. Top-performing schools had an average budget of $3000 per school or $6 per student. Top-performing schools were also more likely to supplement their school-based science budgets with funds from their Parent-Teacher Organizations and/or community-based education foundations.
- **Accessibility of natural resources.** All of the top-performing schools had access to nature trails and other types of natural resources that reinforced classroom instruction and provided real-world, hands-on opportunities for students to learn science.
- **High levels of parent involvement in and advocacy for science.** Parent involvement at top-performing schools was markedly higher than in low-performing schools. All top-performing schools had active Parent-Teacher Organizations that supported science instruction and none of the low-performing schools, reported parent involvement in science. Top-performing schools were also more likely to report having parents that were highly educated, engaged in careers in science and technology, and more likely to engage in science-related learning at home.

There were science-related resources and opportunities which were **relatively consistent** among top-performing and low-performing schools, including:

- **Access to computers.** All of the schools, both top- and low-performing schools reported access to computer labs and classroom computers.

- **The presence of science labs.** Just one of the top-performing schools had a dedicated science lab. The other top-performing and low-performing schools provided science instruction in their regular classrooms.

- **District level science coordinators.** All of the schools had access to district-level science coordinators who ensured that science resources were available and coordinated science-related professional development opportunities.

- **Student to teacher ratio.** There was no marked difference in the average class size for low-performing schools (21 students) as compared with high-performing schools (22 students).

- **Written science curriculum aligned to state frameworks.** All schools in this study had science curricula that were aligned to state frameworks and provided by their districts. *See Appendix C.*

Finally, there was one category in which the low-performing schools had greater emphasis than the top-performing schools:

- **Common planning time.** There was inconsistency among top- and low-performers in terms of common planning time. The top-performing schools in this study provided far less common planning time than their low-performing peers. This finding should prompt further analysis of how common planning time is used and how much of that time is actually devoted to rich discussions of science instruction.

RECOMMENDATIONS

While this study was based on a small sample of elementary schools, and may not be easily generalized to wider populations, clear trends did emerge. The following are some recommendations based on this study's findings and designed to improve the quality of and access to science opportunities for all students.

For school and district leaders.

- **Make science a high priority in schools and across the district.** In general, top-performing schools placed a higher priority on science. School and district leaders need to place greater emphasis on science, and understand that gains in science need not come at the expense of gains in math and ELA.

- **Promote the integration of science with math and literacy.** In order to ensure that science gains do not lead to losses in math and literacy, teachers can develop interdisciplinary links between science, mathematics, and literacy, as well as social studies, physical education and the arts. To do this effectively, teachers will need professional development specifically targeted to cross-curricular integration.

- **Set and monitor guidelines for time on science.** The low-performing schools surveyed were clearly responding to the increased emphasis on students' scores in math and English language arts through a narrowing of the curriculum. While proficiency in math and ELA are critical for students, these are not the only skills needed. Developing districtwide guidelines for time spent on science and monitoring the adherence to those guidelines is a critical step in ensuring that students receive adequate opportunities to learn science.

- **Develop and monitor adherence to science curriculum that is mapped to state frameworks.** All eight of the districts whose schools participated in this study have developed and disseminated science curriculum that is aligned to state frameworks. The next step is for principals and district-level staff to monitor teachers' adherence to the curriculum at the school and classroom level and to hold teachers equally accountable for teaching science as for teaching ELA and math.

- **Support, document, and – if necessary – mandate science-related professional development for elementary school teachers.** Professional development is a critical means for improving instruction in science. Most principals surveyed could not report which of their teachers had participated in science-related professional development and which had not. Without a system for tracking teachers' participation in professional development, it is impossible to assess the areas in which they are most and least knowledgeable. Creating a district-based system for tracking teachers' professional development would be a major step toward systematically addressing the areas in which teachers across all schools in the district need more professional development in science.

- **Identify teachers with high levels of interest in science.** Through hiring, professional development opportunities and ongoing support, develop a cadre of teachers with a high level of interest and knowledge in science. These teachers can become resources for the entire school and district. This study shows that having just a few of these science-focused teachers in a school impacted the entire school's focus on science.

- **Solicit engagement of local business and community leaders in science.** This study reveals the fact that low-performing schools have not had access to or created the same opportunities for science enrichment as top-performing schools. Because low-performing schools are less likely to have parents who are engaged in and advocate for science, they may need to seek other opportunities for students to engage in science – both inside and outside of school. For example, local businesses and employers have a role to play in providing access to enrichment opportunities for students in their communities. Students in low-performing schools and districts could benefit greatly from partnerships with local businesses that provide enriching and engaging science-related activities for students as well as provide science materials and equipment to students. Schools and districts may also consider establishing roles for science mentors who can assist students in science projects and career explorations.

For state policymakers.

Providing more resources and ensuring that all elementary students in Massachusetts have opportunities to learn science and to achieve at high levels will require coordinated efforts by both state legislators and the Department of Elementary and Secondary Education. The following are recommendations for consideration by both state legislators and the Department.

- **Support expanded school day initiatives and encourage more time for subjects like science, especially for low-income and minority students.** The low-performing schools in this study demonstrated their focus on improving math and ELA scores by spending more time on these subjects. Yet, science education is also critical and may provide a viable career path for many students. The two low-performing schools with expanded school days that were highlighted in this study had both opted to increase time in ELA and math exclusively. However, an expanded school day provides schools with an opportunity to increase the amount of time spent in curricular areas like science, without sacrificing time spent on math and ELA. For many students, the traditional six-hour school day simply does not provide enough time for adequate opportunities to learn in all subjects. More time for science and other types of enrichment also provides opportunities to engage students who might not be as successful in other areas of school and creates new pathways for career success. State leaders should support initiatives to expand the school day and allow for additional instructional and enrichment opportunities for students.

- **Provide mentoring and support for elementary teachers to become school-based science resource specialists.** Many of the top-performing schools that participated in this study had access to science resource specialists from the district. The state may consider providing mentors and professional development opportunities for teachers to become science resource specialists. The state may also consider establishing a partnership with the Massachusetts Association of Science Teachers (MAST) to provide professional development and a network of support for science educators.

- **Provide broad, fundamental professional development that is aligned with state frameworks in science for elementary teachers, giving preference to low-performing schools that agree to send a critical number of teachers.** Many of the top-performing schools surveyed had access to teachers with particular expertise in science. Low-performing schools need assistance in developing their teachers' expertise in science. It is also critical that the professional development be of high quality and that the time teachers spend engaged in science-related professional development is used well. State leaders may consider providing competitive grants to support professional development and resources for schools that have developed a clear plan to improve science instruction.

- **Provide technical assistance and training on integrating science, literacy and mathematics instruction.** The top-performing schools surveyed were all integrating science with literacy and mathematics to varying degrees, while few of the low-performing schools reported doing so. State leaders should consider providing assistance for teachers in integrating science with math and English language arts.

- **Support enrichment opportunities for low-performing schools that lack active parent and community engagement in science.** The low-performing schools in this report had minimal to no parent and community support for science. The state has a role to play in assisting these schools with finding and participating in science-related enrichment opportunities. The state may consider providing science coordinators whose role is to help schools develop partnerships with external providers of science-related enrichment opportunities.

- **Provide a supplementary materials budget to under-resourced schools.** Low-performing schools in this study did not have access to school-based funds for science resources and materials. The state may consider making competitive grants available to low-performing schools that present a comprehensive plan for science instruction and a clear rationale for how the funds are to be spent.

POTENTIAL AREAS FOR FUTURE RESEARCH

This study was based on interviews with principals in a small number (13) of Massachusetts elementary schools. In order to fully assess the differences in opportunities to learn science between top-performing and low-performing schools, much additional research is needed. For example, very little is known about elementary school teachers' qualifications and expertise in science. Large-scale surveys of individual teachers' science-related coursework and professional development would provide opportunities to analyze the links between teachers' expertise in science and their effectiveness in teaching science. More research at the classroom level is also necessary. This study captured information at the school level. In order to accurately assess what happens at the classroom level, research must be conducted using classroom observations, teacher surveys and teacher interviews.

CONCLUSION

Opportunities for students to participate in engaging and challenging science instruction are essential to effectively prepare them to engage in the increasingly science- and technology-oriented world in which they live. It is indefensible that the students who are least likely to get exposure to and support for science-related learning from parents and their communities are the same students that are most likely to have diminished opportunities to learn science during their school day. This research strongly suggests that 1) too many low-income and urban students in Massachusetts are short-changed when it comes to time spent on science, access to material resources, and access to teachers who are excited and knowledgeable about science; and 2) that it is possible for schools with high percentages of low-income students to educate students to high levels in science. This report begins to outline strategies that school, district and state leaders can consider as they work to improve the opportunities for all students to learn and achieve success in science.

Endnotes

1 Lind, K.K. (1999). Science in Early Childhood: Developing and acquiring fundamental concepts and skills. American Association for the Advancement of Science. Washington, DC.

2 McMurrer, J. (2007). Choices, changes, and challenges: Curriculum and instruction in the NCLB Era. Center on Education Policy. Washington, DC.

3 Massachusetts Statewide STEM Indicators Project: Overview of Indicators and Year One Data. (July 2006). University of Massachusetts Donahue Institute.

4 University of Massachusetts Donahue Institute & Massachusetts Department of Higher Education. (2008). *Massachusetts Statewide STEM Indicators Project (MASSIP): Year Two Data.*

5 The Massachusetts Mathematics, Science, Technology & Engineering Grant (Pipeline) Fund was established under the Acts of 2003 Economic Stimulus Trust Fund. The Massachusetts Department of Higher Education (DHE) was directed to administer the Pipeline Fund with a focus on three goals: to increase the number of Massachusetts students who participate in programs that support careers in STEM fields; to increase the number of qualified STEM teachers; and, to improve the STEM offerings available in public and private schools.

6 University of Massachusetts Donahue Institute & Massachusetts Department of Higher Education. (2008). *Massachusetts Statewide STEM Indicators Project (MASSIP): Year Two Data*.

7 The Composite Performance Index (CPI) is a measure of the extent to which students are progressing toward proficiency. The CPI is a 100-point index that combines the scores of students who take standard MCAS tests (the Proficiency Index) with the scores of those who take the MCAS-Alternate Assessment (MCAS-Alt) (the MCAS-Alt Index).

8 McMurrer, J. (2008). Instructional time in elementary schools: A closer look at changes for specific subjects. Center on Education Policy. Washington, DC.; Dorph, R., Goldstein, D., Lee, S., Lepori, K., Schneider, S., Venkatesan, S. (2007). The status of science education in the Bay Area: Research Study e-report. Lawrence Hall of Science, University of California. Berkeley, CA.

9 Understanding by Design (UbD) was developed by Grant Wiggins and is a framework for designing curriculum units, performance assessments, and instruction that lead students to deep understanding of the content being taught. For more information, visit www.ubdexchange.org.

10 Inquiry based approaches to science education focus on student constructed learning as opposed to teacher-transmitted information.

11 Lucy Calkins is a professor at Teacher College, Columbia University, who co-authored the book *A Teacher's Guide to Standardized Reading Tests: Knowledge is Power.*

APPENDIX A: Elementary School Audit Survey Questions

A. SCHOOL CONTEXT

1. Total number of students.
2. Percent of students by race/ethnic groups.
3. Percent of ELL students.
4. Percent of special education students.
5. Percent of low-income students.

B. OPPORTUNITIES

1. **Kindergarten** How much time per week is spent on science? Is science a semester-long course or year-long course? What subject areas taught?
2. **Second Grade** How much time per week is spent on science? Is science a semester-long course or year-long course? What subject areas taught?
3. **Fifth Grade** How much time per week is spent on science? Is science a semester-long course or year-long course? What subject areas taught?

C. STAFFING

1. Are any faculty members certified in science? If yes, how many and in what are they certified?
2. Does the school have a science coordinator, coach or specialist? If yes, how many hours per week is the science coordinator at the school?
3. Does the district have a science coordinator, coach or specialist? If yes, how many hours per week is the science coordinator at the school?
4. Does the school have a budget for science? What are the major budget items related to science?
5. What is the average class size? Is this different for science classes? If yes, what is the class size for science classes?

D. CURRICULUM

1. What curriculum is used? (Publisher or developed by school/teacher). Describe the science curriculum in Kindergarten. In second grade. In fifth grade.
2. What are the criteria for selecting/developing instructional materials?

E. FACILITIES/RESOURCES

1. Presence of laboratories in school.
2. Lab equipment/supplies: (e.g. sinks, benches, water, microscopes, beakers, measurement equipment). What lab materials do you have?
3. Technology resources: audiovisual equipment (projectors, television, DVD player, smartboards, probeware, etc.). Computers (number of computer labs, ratio of computers per student, on-line streaming, scientific software, etc.).
4. Other resources (e.g. nature trail, pond or other natural resources).

F. ENRICHMENT OPPORTUNITIES

1. Science clubs or extra-curricular science activities.
2. School partnerships with science organizations (e.g. Boston Nature Center, nonprofit organizations focused on science, institutions of higher education).
3. Describe any science-related support, activities or resources that parents provide. Examples of this support include (e.g. parent led field trips, clubs).
4. Describe any science-related support, activities or resources that the community provides.

G. STUDENT SUPPORT

1. What support is available for students who need extra help in science?

H. TEACHER SUPPORT

1. Professional development for science provided during the 07-08 school year (mandatory or voluntary).
2. Science-focused mentoring for first year teachers.
3. How often are teachers evaluated (per year)? How are teachers evaluated?
4. Teacher collaboration: How many minutes per month do teachers work collaboratively on teaching and learning? Is any of this time dedicated to science instruction? If yes, provide an example of this.

I. SCHOOL SUPPORT

1. Does your school have an improvement plan for science? If yes, describe some of the goals.

APPENDIX B: Sample Elementary Science Curriculum Pacing Guide

Arthur Talmadge Elementary School, Springfield, MA

	September	October	November	December	January	Mid-Year Exam	February	March	April	May	June	Final Exam
Kindergarten	**Senses** *Seeing, Touching, Hearing*	**Senses** *Smell, Taste*	**Myself & Others** *Physical Traits*	**Myself & Others** *Inherited Traits*	**Myself & Others** *Graphing, Comparing*		**Weather** *Measuring wind; thermometers*	**Weather** *Water cycle; weather instruments*	**Living Things** *Variables; living/nonliving*	**Living Things** *Sun (grow light); Reproduction*	**Living Things** *Common needs; inherited traits*	
First Grade	**Balls & Ramps** *Properties of balls*	**Balls & Ramps** *Variables*	**Solids & Liquids** *Properties of Solids*	**Solids & Liquids** *Properties of Liquids*	**Solids & Liquids** *Comparing solids v. liquids*		**Growing Things** *Seeds; germination*	**Growing Things** *Needs of plants, structure*	**Organisms** *Comparing water/land plants*	**Organisms** *Comparing water/land plants*	**Organisms** *Common needs of living things*	
Second Grade	**Insects** *Needs, characteristics*	**Insects** *Life cycles; metamorphosis*	**Changes** *Solids, liquids*	**Changes** *Gases, separating solids*	**Changes** *Physical & chemical change*		**Sound** *Vibration; pitch*	**Sound** *Sound-energy, solid-liquid-gas*	**Sound** *Describing sound; making instruments*	**Balancing & Weighing** *Observable properties; comparing*	**Balancing & Weighing** *Design features; appropriate materials*	
Third Grade	**Plant Growth & Development** *Life cycles; variables*	**Plant Growth & Development** *Needs of plants; harvesting*	**Solar System** *Rotation, revolution*	**Solar System** *Movement of bodies; gravity*	**Solar System** *Reflecting light, shadows*		**Circuits & Pathways** *Simple series circuits & conductors*	**Circuits & Pathways** *Parallel circuits; electromagnets*	**Habitats & Animal Classifications** *Basic needs; classifying*	**Habitats & Animal Classifications** *Adaptations; physical factors*	**Habitats & Animal Classifications** *Food chains; changing environments*	
Fourth Grade	**Reading the Environment** *Change; weathering*	**Reading the Environment** *Geologic time, erosion*	**Rocks & Minerals** *Properties; rock cycle*	**Rocks & Minerals** *Minerals; field tests*	**Rocks & Minerals** *Field tests; comparing*		**Weather** *Components of weather; weather v. climate*	**Weather** *Water cycle; Weather instruments*	**Weather** *Global patterns*	**Changes of State** *Solid-liquid-gas; matter*	**Changes of State** *Insulation; design tasks*	
Fifth Grade	**Bones & Skeletons** *Major bone groups*	**Bones & Skeletons** *Joints, movement*	**Bones & Skeletons** *Comparison; adaptation*	**Lifting Heavy Things** *Moving objects, matching tools/purpose*	**Lifting Heavy Things** *Inclined plane; pulleys & levers*		**Lifting Heavy Things** *Screw, wedge, wheel; simple/complex machines*	**Light/MCAS Review** *Forms of energy; energy transformation*	**Light/MCAS Review** *Solar system; electricity; sound*	**Microworlds** *Living/nonliving; microscopes*	**Microworlds** *Growth, reproduction; need for food, air and water*	

APPENDIX C: Sample Science Curriculum from a Top-Performing Elementary School

	Life Science	Earth/Space Science	Physical Science
Kindergarten	Nutrition Schoolyard Science	The Changing Seasons	Floating/Sinking
Grade 1	Organisms	Weather	Solids and Liquids Balls and Ramps
Grade 2	Life Cycles Plant Growth and Development	Sounds Rocks, Minerals and Fossils	Balance and Motion Sounds Rocks, Minerals and Fossils
Grade 3	Soils Owls/Web of Life	Soils Owls/Web of Life	Chemical Tests and Electric Circuits
Grade 4	Life Cycle of Plants	Land and Water Astronomy and Weather	
Grade 5	Ecosystems The Transport Systems	Ecosystems	Simple Engineering
Grade 6	Microworlds		Science and Engineering Energy Sources