Helping Students Learn Science Through Writing And Writing Through Science

Key Findings from Ten Years of Study

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INVERNESS RESEARCH

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Executive Summary

Over the past decade, Betsy Rupp Fulwiler and a team of K-5 lead teachers in Seattle Public Schools have developed and refined a highly effective approach to teaching writing in science to elementary school students. Over ten years, Inverness Research has conducted four major studies of the approach, referred to as the Science-Writing Approach (SWA). This monograph draws from this large body of research to explain how the approach helps teachers strengthen both science and writing instruction and how it benefits students, including students who are English language learners. The monograph also explains the supports that teachers need to implement the approach and assesses prospects for scaling up the approach. Our hope is that this monograph will provide districts across the nation with the information and encouragement they need to familiarize themselves with this approach to teaching elementary science and expository writing and to seek the supports they need to put it into action in their classrooms.

The need for an effective science-writing approach

A convergence of several factors-the nature of this approach of teaching science with writing and writing in science, the national need for improvement in science instruction, and the availability of research showing the effectiveness of the approach-make it both timely and important that educators gain broader awareness. First, this integrated approach enhances scientific thinking and conceptual development in science, teaches forms of expository writing that are vitally important for elementary students to learn, and promotes academic language development for all students, including English language learners. Furthermore, the Science-Writing Approach's practices of science and scientific literacy are consistent with the *NRC Framework for K-12 Science Education* and can help support implementation of the *Next Generation Science Standards*. Importantly, two publications by Fulwiler—*Writing in Science: How to Scaffold Instruction to Support Learning* (2007) and *Writing in Science in Action: Strategies, Tools, and Classroom Video* (2011)—make the theory and practices of the approach accessible across the nation and internationally.

Finally, multiple studies document the value of the approach. Three Inverness studies include classroom observations, teacher surveys, and in-depth analysis and assessment of the work in student science notebooks, drawing from the perspectives of teachers, administrators, and independent outside experts in science and literacy. A pilot study by the UCLA Center for Research on Evaluation, Standards, and Student Testing (CRESST) examines the relationship between the Science-Writing Program and state science assessment. A study of implementation in districts in multiple states examines the process and explores the promise the approach holds beyond Seattle.

Evidence of the effectiveness and scalability of the Science-Writing Approach

Evidence from the body of evaluation research supports four key claims about the approach.

Claim 1: Science writing improves the teaching of science and of writing

A general finding across the Inverness studies is that teachers within and beyond Seattle, school and district administrators, and independent outside experts all value the approach's integration of science and expository writing and judge that it benefits teaching and student learning.

Specific findings from studies in Seattle:

Science-Writing Program participants teach more and better science than non-participants. Participants in the Science-Writing Program on average spend more time teaching science, teach more writing in science, have higher expectations for students with special needs, and follow the district's science curriculum more consistently than teachers who have little or no experience with the program. Participants are also more likely than non-participants to increase their teaching of science from one year to the next and to teach more science than others in their school.

Teachers attribute improvements and greater confidence in teaching to the Science-Writing Program. Seattle's high quality professional development in science and in science writing gives teachers who are committed to teaching science, but who are not confident about their ability, the means to teach science better by giving them the resources and strategies they need to improve their teaching of hands-on, inquiry science, and to improve their teaching of writing.

The strategies of the Science-Writing Approach translate from science and apply to other subjects as well. Teachers find that the strategies translate quite naturally to other subject areas, such as social studies, offering students similar opportunities to express their reasoning across the curriculum.

Independent panels of science education experts find that the Science-Writing Program helps Seattle teachers improve their science teaching. Independent outside science education experts find that the Seattle student notebooks stand out from ones they have seen in other districts around the nation because they contain a greater amount of student writing overall, they reflect a much more deliberate and systematic approach to developing students' writing and science skills, and they offer students greater opportunities than typical science notebooks to formulate and express concepts in science.

Claim 2: The Science-Writing Approach improves learning for a wide range of students

Evaluation studies identify multiple ways that the approach contributes to student learning.

The Science-Writing Approach helps students move from hands-on investigation to concept development. Teachers and outside reviewers perceive that the approach to teaching writing, in conjunction with hands-on inquiry-based science curriculum, helps teachers engage students in purposeful investigations accompanied by writing to make the elusive but all-important link between investigations and conceptual sense-making.

The Science-Writing Approach helps students learn to do expository writing starting in kindergarten. Independent reviewers of student notebooks, principals outside of Seattle who have come to know the program, and classroom teachers who use the SW approach with their students speak out about the importance of explanatory and analytic writing as a part of students' repertoires, beyond the narrative forms more typically taught in elementary grades. Hands-on, investigation-based science is a fertile context for the teaching and learning of expository writing because the writing fosters thinking about and internalization of concepts through language; the science experience generates important, compelling content about which to write. Teachers using the approach report that students feel more motivated to write and are prouder of what they write in their science notebooks than in other writing.

The Science-Writing Approach holds potential for "leveling the playing field" for different student populations. Inverness Research's in-depth studies of student writing in science notebooks in the Seattle program suggest that the approach has potential for contributing to more equitable achievement for learners with special needs. Independent reviewers judge the approach to be especially effective in supporting the learning and language development of English Language Learners (ELL) and others struggling with literacy in English. Additionally, teachers involved in the program develop higher expectations for ELL students and students below grade level; in fact, the more experience a teacher has with the Science-Writing Approach, the more likely she is to believe that writing is helpful not only to the most able, high-achieving students, but also to low-performing and special needs students.

The Science-Writing Approach shows potential for improving test scores and meeting standards. A pilot study conducted by the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) showed that students of SWA program participants outperformed students of non-participants on the 2004 5th grade state science assessment. Teachers and outside reviewers also judged that the strategies of the approach were aligned well with the science and writing standards of the time. The approach is also consistent with the *NRC Framework for K-12 Science Education* on which the *Next Generation Science Standards* are being developed.

A caution related to the approach that emerged from the research is that teachers can implement it in a way that over-relies on the scaffolds or does not wean students off of them when they are ready, hindering students from grappling more authentically with their inquiry and their independent thinking.

Claim 3: Putting the approach into practice requires a foundational inquiry-based science curriculum and a variety of professional development supports

Studies of the full Seattle implementation strategy. Seattle Public Schools supports a K-5 science program that includes three hands-on, inquiry based units (or "kits") per grade level per year (totaling 18 units K-5), with professional development workshops that focus on the science content and instructional strategies for those units. The Science-Writing Program is built on this foundation and has three components of its own—7.5 hours of professional development classes, a writing supplement to each science unit, and teacher leadership development meetings. With this full complement of introductory and grade-level specific workshops, supplemental science-writing curriculum for each of the science units, and support from teacher leaders, teachers who are committed to the approach and are working in a school where time is given to science can achieve quite full implementation in two or three years.

Studies of implementation without full program support. Participation in Seattle is voluntary. In a study of 18 Seattle teachers who received less than 4.5 hours of professional development, we found that 8 of 18 teachers implemented the approach strongly, 7 partially or minimally, and 3 not at all. The study concluded that even minimal implementation of the Science-Writing Approach is better for students than no use of the approach. While full implementation is needed for full benefits to students, modest implementation has some benefits and few detriments.

Teachers outside of Seattle had access to one published book (Fulwiler, 2007) as well as draft support materials for the second book (Fulwiler, 2011), such as study group protocols which promoted analysis of models of teaching on a DVD as well as guidelines and criteria for examining work in student notebooks. In one study, 15 of 23 pilot teachers were able to implement a few key strategies that got students started writing in science. Studies in a range of districts showed that teachers working in districts with stronger foundational science programs and more science leadership were able to move farther along a trajectory of implementation than teachers with weaker science programs. Where there was a weak science program and little teacher leadership, the first book and additional supports were essential for teachers to include any writing at all in their science teaching. However, that level of support was not sufficient for them to reach fuller levels of implementation.

Optimal implementation conditions outside Seattle. In the one district outside Washington where there was a strong and well-supported science program and sustained investment in teacher leadership, we saw that highly competent science teachers could skillfully implement the approach. The results in this national context[1] demonstrated what is needed to move to fuller implementation in the

[1] In this state teachers participated from a number of different small districts that belong to a consortium, which continues to work together to provide professional development and other support for teachers in kit-based hands-on science. It started as a NSF Systemic Change Initiative.

absence of Seattle's comprehensive support. The fuller implementers in this context were teacher leaders: master teachers who provide professional development to other teachers for science teaching in districts that have well-developed and sustained kit-based, hands-on science programs. The teacher leaders taught hands-on science with confidence and understanding. A regional consortium provided elementary teachers with unit and grade-level-specific professional development in science; then, as part of this study, the consortium began to include science writing in introductory kit trainings. Six out of eight superintendents in this consortium purchased the first book, *Writing in Science*, for all teachers in their districts. Importantly, the teacher leaders had additional local support from their principals for implementing science writing, which pilot teachers in other states we studied did not have. These principals were highly involved in and supportive of the study groups and implementation of the Science-Writing Approach. In fact, their entire schools were actively participating in the study groups and moving toward school-wide implementation of the approach.

Claim 4: There is a Need for, a Model for, and Leadership Capacity for Launching a National Professional Development Institute for Science Writing

In February 2011, Fulwiler and a core group of LSWTs and administrative staff in Seattle rose to the call for professional development in the Science-Writing Approach by piloting a national Writing in Science Institute. Inverness conducted a formative evaluation of the institute.

The institute was of high quality and value to participants. We found that the institute was well designed to serve teachers at all levels of implementation and that it greatly enhanced what they learned from the two *Writing in Science* books. For teachers in the more initial stages of implementation, the institute offered enough experience with science notebooks and expository writing to enable them to understand the basics of this Science-Writing Approach and how it is distinct from many district-prescribed writing curricula. For the fuller implementers, the institute illuminated the more challenging aspects of the approach, such as how students' oral reflection on their inquiry experience is an integral part of the writing process, and how to facilitate the interface between the science experience, science conceptual development, and the writing. All participants benefited from the opportunities the institute offered to rethink assessment and learn new ways of learning from and responding to student work.

The Institute built Seattle's leadership capacity to serve a national audience. The institute offered five of Seattle's most experienced Lead Science Writing Teachers their first formal opportunity to provide professional development on the Science-Writing Approach, and to serve a national audience. The experience of contributing to the institute served as an important leadership capacity-building vehicle for these leaders, and they have growing confidence and desire to extend their leadership growth and opportunities both within and outside of Seattle.

The Science-Writing Approach as an investment in educational improvement

The gap between where U.S. students are in their science learning and where they need to be, combined with the development of rigorous new standards in science, create a climate of urgency for addressing the need to scale up effective science and science literacy programs. The evidence collected over ten years of evaluation shows that the Science-Writing Approach offers a solution. The approach enhances elementary teachers' confidence and skills in teaching science. It offers students, including English language learners and special needs students, powerful opportunities to learn science concepts, scientific thinking and practices, and expository writing. Scaling up the Science-Writing Approach will require a national strategy-one that includes support for a national institute as well as a network infrastructure supporting national and local leadership development. Seattle's successful pilot Writing in Science Institute, in combination with an emergent network of teachers and districts that are implementing the approach, are key building blocks for this strategy.

Introduction

Over the past decade, Betsy Rupp Fulwiler and a team of K-5 lead teachers in Seattle Public Schools have developed and refined a highly effective approach to teaching writing in science.[2] This approach—which we refer to as the Science-Writing Approach—started in Seattle but has expanded to a national audience. Having conducted four major studies as it evolved, Inverness Research knows the Science-Writing Approach well, including the program of professional development and leadership in which it is disseminated in Seattle (we refer to this as the Science-Writing Program). In this monograph we look back over the history of development and research on this approach to teaching science and writing together. Our research examines how the approach helps teachers strengthen both science and writing instruction and how it benefits students, including students who are English language learners. The monograph also looks at the scalability of the approach and the supports that teachers need for full implementation and full benefits to student learning.

Our purpose in preparing this monograph is to illuminate how the Science-Writing Approach can make invaluable contributions to teachers, schools, and districts interested in improving their students' development in science and in writing, and to make a case for the kind of ongoing support that teachers need to realize the full benefits of the program. Our hope is that this monograph will provide districts across the nation with the information and encouragement they need to explore this approach to elementary science and to seek the supports they need to put it into action in their classrooms.

I. The Need for an Effective Science-Writing Approach

We see four major reasons why it is timely and important to build broader awareness about a well-tested approach to teaching writing in science and science with writing.

An integrated science-writing approach has an important place in elementary education

The Science-Writing Approach integrates expository writing and inquiry-based, hands-on science in a structured program. In Seattle, the Science-Writing Program consists both of a curriculum for writing linked to the district's science kits and professional development workshops for integrating science and writing. The program has real potential for classroom implementation beyond Seattle because it

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[2] The development of the Science-Writing Approach was supported by a series of grants from the Stuart Foundation, the National Science Foundation, the Nesholm Family Foundation, and Lee and Valerie Hood. The Science-Writing Program was administered by Seattle Public Schools science Program Manager, Elaine Woo, and Program Assistant, Penny Knutzen.

takes an explicit and structured approach to teaching writing in science and is designed to integrate into a hands-on science curriculum.

The approach has several key features that are of interest to educators. One is that it integrates writing into an inquiry-based science curriculum in structured ways that enhance scientific thinking and conceptual development in science. Another is that it teaches genres of expository writing that typically are not taught in the elementary grades yet are vitally important for all students to learn. It teaches such writing skills in a meaningful context of hands-on science experiences. Third, the integration of science and writing promotes academic language development and disciplined thinking for all students, including English language learners.

The time is right for disseminating the Science-Writing Approach

Understanding the current national context for K-12 science education underscores the need for and potential value science writing holds for our students. Compared with students in other nations, U.S. students maintain a mediocre standing on international science assessments, and, as they move up the grade levels, the comparisons tend to be less favorable. U.S. high school students ranked 17th on the science portion of the 2009 PISA.[3] Comparisons of TIMSS scores show that in 2007 the average U.S. fourth grader's science score was lower than the average in four countries. In eighth grade the U.S. average was lower than those in nine countries (Kerachsky, 2008). We see similar trends nationally. Over a third of U.S. eighth grade students scored below "basic" on the 2009 NAEP science assessment (NRC, 2012b; NCES, 2011). In fourth grade, NAEP comparisons show that there was an increase in students' science performance both overall and among boys between 1996 and 2005. NAEP also reported increases in science performance for four of five racial/ethnic subgroups (white, black, Hispanic, Asian/Pacific Islander) at fourth grade. At the eighth grade level, NAEP scores did not show any change in science performance among students overall (NCES, 2011: 13).

The nation's desire is to prepare students to be informed citizens for effective participation in a democracy at home, and to be competitive in a global environment fueled by and demanding innovations in science, engineering, and technology. We face challenges on a global scale from pandemics to energy shortages—challenges that require scientific and technological know-how to tackle. The International Science Benchmarking Report states the need as follows:

> U.S. students have consistently lagged behind their peers in other nations on international science assessments—a performance increasingly at odds with the challenge of being able to live and compete in a global environment, powered by innovations in science, engineering and technology. A strong foundation in science is clearly critical if today's students are to have the option of pursuing careers in STEM-related fields where employment opportunities are expanding. But the ability to compete in a world economy is not the only issue. More than

[3] All acronyms are defined in the Glossary of Acronyms at the end of the monograph.

> ever, participating as an informed citizen in a democracy, and making personal decisions, requires the ability to digest current events and make judgments based upon scientific evidence. National efforts in science education are focusing on two key issues: scientific literacy for all students and STEM preparedness to increase the STEM pipeline (Achieve, 2010: 2).

The *Framework for K-12 Science Education* adds urgency to this need, placing STEM preparedness at the center of humanity's dilemma:

> Many recent calls for improvements in K-12 science education have focused on the need for science and engineering professionals to keep the United States competitive in the international arena. Although there is little doubt that this need is genuine, a compelling case can also be made that understanding science and engineering, now more than ever, is essential for every American citizen. Science, engineering, and the technologies they influence permeate every aspect of modern life. Indeed, some knowledge of science and engineering is required to engage with the major public policy issues of today as well as to make informed everyday decisions, such as selecting among alternative medical treatments or determining how to invest public funds for water supply options. In addition, understanding science and the extraordinary insights it has produced can be meaningful and relevant on a personal level, opening new worlds to explore and offering lifelong opportunities for enriching people's lives. In these contexts, learning science is important for everyone, even those who eventually choose careers in fields other than science or engineering (NRC, 2012a).

Efforts are underway in the science and science education community to address the gap between where our students are and where we want them to be. The National Research Council (NRC) recently finalized the *Framework for K-12 Science Education*, which lays out the practices and habits of mind that students need to learn, as well as broad crosscutting concepts and core disciplinary ideas for K-12 science education (NRC, 2012a). The practices outlined are those of hands-on, inquiry science (e.g., asking questions, planning and carrying out investigations, developing and using models) and of scientific literacy (e.g., analyzing and interpreting data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information). This Framework sets the vision for the *Next Generation Science Standards*, the development of which is underway (see http://www.nextgenscience.org/). Common Core (2009) further maintains that "a comprehensive, content-rich curriculum," similar to what high performing countries on international assessments offer their students, is the disciplinary foundation necessary to close the achievement gap.

Integrating the teaching and learning of writing and science makes good sense in this context. The evidence in this report supports the claim that academic language development and expository writing paired with strong science content learned through hands-on exploration and investigation hold great promise for meeting the call for improved student learning of science and science literacy.

High quality materials now exist to support this integrated approach to teaching science and writing

The materials that portray the Science-Writing Approach are now available for teachers and districts outside of Seattle to learn how to implement the Science-Writing Approach. The approach is fully rendered in two publications—*Writing in Science: How to Scaffold Instruction to Support Learning and Writing in Science in Action: Strategies, Tools, and Classroom Video* (Fulwiler, 2007, 2011). They make the theory, practices, and knowledge about how to successfully implement the approach accessible to interested teachers and districts across the nation and internationally. They were created with an exceptionally high level of scrutiny and feedback both from the perspectives of piloting teachers in different contexts nationally and from Inverness Research, who served as the external evaluator for materials development and piloting. This feedback informed revisions throughout a three-year development process.

The publications are flexible enough to include as their audience individual teachers, study groups of teachers working together, and/or professional developers in elementary science. The Science-Writing Approach is meant to accompany a research-based, hands-on science program, and is ideally supported by a well-specified program for professional development for both science and writing. The reality is that outside of Seattle, where the Science-Writing Approach developed, most districts and schools in the country do not offer this kind of support in science at present. The publications address the fact that professional development will likely not be available to support teachers in learning to implement science writing.

Inverness' studies document the value of the approach to the teaching and learning of science and writing

Inverness conducted three in-depth studies of the Science-Writing Program in Seattle and a fourth in national contexts. Each takes a slightly different angle on studying the approach, but they also share three common threads: They all include the perspectives of teachers on the value of the approach to their teaching and to student learning; they all involve analysis of student work in science notebooks for evidence of benefits to student learning; and they all look for ways Seattle might refine and improve this work.[4] The first three studies also elicited the perspectives of independent experts in science and literacy education who reviewed and analyzed student work in science notebooks (Stokes, et al., 2002, 2003, 2005).[5]

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[4] Data sources included student science notebooks, classroom observations, teacher and administrator interviews, and teacher surveys. See the referenced reports for more on data sources and methods.

[5] Additionally, the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) at UCLA conducted a pilot study of the effects of Science-Writing Program participation on science learning as measured by state science assessments. In this monograph, we refer to findings from this study (Choi and Herman, 2005).

The first of the Inverness studies (Stokes, et al., 2002) looks at the benefits of the Science-Writing Approach for students in classrooms of teacher leaders who were fully implementing the approach, and teachers' perspectives on the value of the approach for their teaching and for student learning.

The second study (Stokes, et al., 2003) expands our focus, asking how and to what extent the approach contributes to student learning in ways that are important to Seattle Public Schools but also to the broader context of the science education reform community. Independent experts reviewed student notebooks to capture their perspectives on the key features, the quality, and the educational significance of student work in science notebooks. This study asks a second question, which is how widely and to what degree teachers are implementing the program in Seattle and how do participants in the Science-Writing Program compare with other elementary teachers.

The third study (Stokes, et al., 2005) investigates implementation by "typical" science teachers who have taken just a few workshops. The student notebook analysis looks at whether benefits are associated with partial implementation as well as full implementation of the approach.

The fourth and most recent study is based on the work of Seattle's NSF-funded *Designing Professional Development Materials that Lead to Effective Science and Expository Writing Instruction*.[6] Inverness studied teachers in five states—Washington, Maine, Arizona, Rhode Island, and South Carolina—who used *Writing in Science* and piloted an implementation curriculum that is now included in *Writing in Science in Action*. The project offered an opportunity for studying the implementation of the Science-Writing Approach outside of Seattle and provided formative feedback to the author for refining the materials for publication.

The fourth study asks what promise the approach holds for teaching and learning science writing in classrooms without the benefit of a well-specified professional development program such as Seattle offers in conjunction with its kit-based science program. We reasoned that this set of circumstances represents the reality in most districts around the nation. The study also asks what it takes, under these circumstances, for teachers to put the approach into practice and what benefits it has for student learning in these contexts. Thus, this study generated knowledge about the "implementability" of the approach and its educational significance in these varied contexts with no outside support. The fourth study also included evaluation of a pilot national teacher institute for science writing offered in Seattle in February 2011.

[6] There is no separate report for this last study, which served a primarily formative purpose. In this monograph we draw from what we learned in that study.

II. Evidence of the Effectiveness and Scalability of the Science-Writing Approach

In this section we draw from our evaluation studies to support four key claims about the Science-Writing Approach. Claims 1 and 2 refer to the qualities and benefits of the Science-Writing Approach in teaching and learning. Claims 3 and 4 refer to what it takes to implement the approach and to support its dissemination beyond Seattle. Claim 1 is that the approach improves the quality of teaching. Claim 2 is that the approach benefits a wide range of students. Claim 3 is that putting the approach into practice requires an inquiry-based science curriculum and a variety of professional development supports. Claim 4 is that a model and leadership capacity exist that can launch a national professional development institute for science writing.

CLAIM 1: Science Writing Improves The Teaching Of Writing And Of Science

The Inverness studies sought to learn the extent to which the program influenced teachers' teaching in ways that benefit student learning. In order to ensure the accuracy of our understanding, our studies gathered perceptions from classroom teachers in both Seattle and elsewhere, Seattle lead teachers, and panels of independent reviewers who were asked to analyze student work in science notebooks in Seattle and share their thoughts and perceptions about the quality of teaching in the program based on what they saw in the student work.

A general finding across all studies is that **educators value the integration of science and expository writing and think it benefits teaching and student learning**. Independent science education experts find that the Seattle student notebooks stand out from ones they have seen in other districts around the nation because they contain a greater amount of student writing overall, they reflect a much more deliberate and systematic approach to developing students' writing and science skills, and they offer students greater opportunities than typical science notebooks to formulate and express their ideas in science. (Stokes, et al., 2002: 40) Seattle's Lead Science Writing Teachers (LSWTs) and school and district administrators who analyzed their students' science notebooks agree that the Science-Writing Approach is an important dimension of the kit-based science curriculum and that the program meets the practical instructional needs of teachers. (Stokes, et al., 2003) Classroom teachers in Seattle and elsewhere find that the approach supports their teaching of science and expository writing and benefits students' learning of both.

Classroom teachers familiar with the approach express the need to teach students science writing and are convinced that this approach works. A third grade teacher explains the value of it in this way:

> [Students] don't know how to explain their reasoning, for instance, unless we teach them. They don't know how to analyze data and interpret it, unless we teach them. This is what the writing is doing for kids.[7]

A second grade teacher outside of Seattle reports that teachers are so convinced that science writing works that the entire school is now implementing it:

> Knowing that, number one, it works, and, number two, we are seeing the results that we need and just everybody onboard, and it is amazing that everybody was in complete agreement that we should try this and that everybody really liked it and I think that is a major support.

Our studies generated a number of specific findings associated with the strengthening of teaching:

- **Seattle's Science-Writing Program participants teach more and better science than non-participants**

Participants in the Science-Writing Program[8] on average spend more time teaching science, teach more writing in science, have higher expectations for students with special needs, and follow the district's science curriculum more consistently than teachers who have little or no experience with the program.[9] Participants are also more likely than non/limited-participants to increase their teaching of science from one year to the next and to teach more science than others in their school.

The following table displays the results of several survey items that ask about the extent to which teachers include writing in science. It shows that participants teach writing in science to a greater extent than non/limited-participants.

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[7] The quotes in this report have been lightly edited for clarity without changing the intended meaning of the speaker. The quotes from student notebooks are shown verbatim; see footnote 13.

[8] Whenever we refer to the Science Writing Program we are referring to Seattle Public School's program which implements the Science-Writing Approach with a program of professional development classes and writing units that supplement the inquiry-based hands-on science curriculum.

[9] "Participants" refer to teachers who participated in 2 or more science-writing workshops between 2000–03; and "non/limited-participants" are teachers randomly selected from all Seattle elementary schools who did not fit the definition of participant. Defining the samples in this way had the potential to reduce the contrast between the two groups, because two (or more) workshops in three years cannot be deemed "heavy" professional development; also, the sample of "non/limited-participants" included some teachers who had participated in one workshop offered by the program within the past three years and perhaps a few who had taken two in four years. Given this, it is especially impressive that there are many significant differences between the two groups with respect to the teaching of science and the teaching of writing in science.

Table 1. The extent of the teaching of writing in science

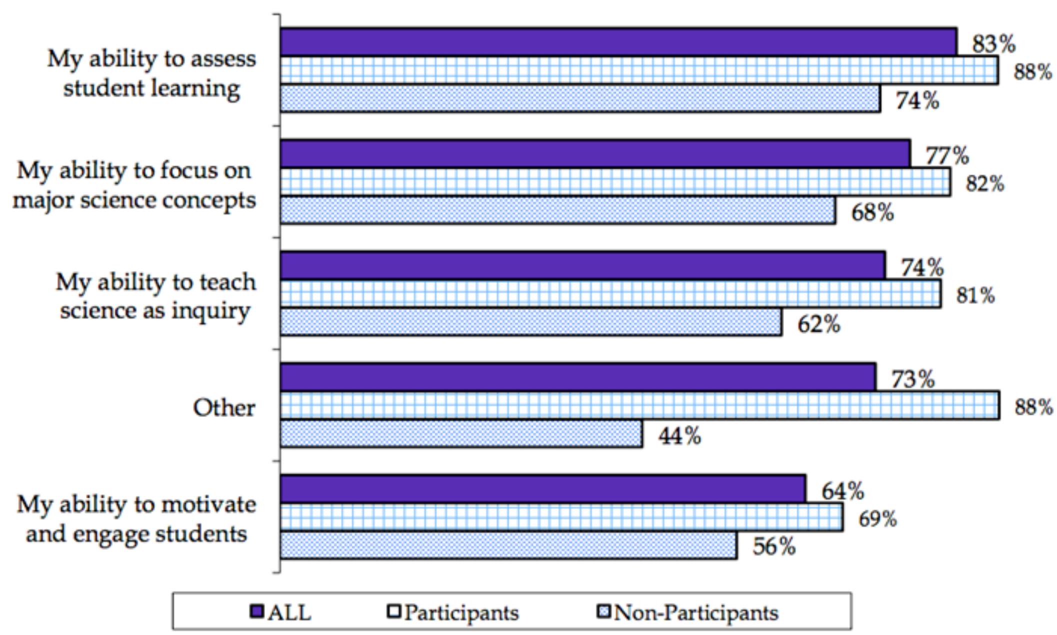
Teaching *Writing in Science*	**Participants in Writing Program**	**Non-participants**	**All**
**Proportion of science lessons where students are asked to write	75% (median) 67% (mean)	50% (median) 51% (mean)	65% (median) 60% (mean)
**Percentage of teachers who have students write in science: 3-5 days a week 2 days a week	 30% 45%	 18% 38%	 24% 42%
**Number of minutes per week in which students write in science	40 (median) 47 (mean)	30 (median) 37 (median)	40 (median) 43 (mean)
**Percentage of science lessons in which teachers used prompts from the Science-Writing Program	80 (median) 70 (mean)	30 (median) 39 (mean)	65 (median) 60 (mean)
Percentage of teachers who spend more time on writing in science than other teachers in their schools	53%	35%	45%
Percentage of teachers who spend more time on writing in science this year than last year	51%	45%	49%

***Differences for these items are statistically significant at p=<.003*

- **Teachers attribute improvements and greater confidence in teaching to the Science-Writing Program**

Seattle's high quality professional development in science and in science writing gives teachers who are committed to teaching science, but who are not confident about their ability, the means to actualize their personal commitment. Seattle teachers say that the Science-Writing Program helps them teach science better by giving them the resources and strategies they need to improve their teaching of hands-on, inquiry science, and to improve their teaching of writing. The graph below shows that compared with teachers who had spent less or no time in the science-writing classes, teachers who had participated in the classes gave themselves higher ratings in their ability to assess student learning, focus on major science concepts, teach science as inquiry, and motivate and engage students.

Figure 1. Percentage of teachers reporting ways in which the science-writing classes have enhanced teaching of district science units



Percentages represent teachers who marked "4" or "5" on a 5-point scale where "1" = "greatly diminished" and "5" = "greatly enhanced." For each of the four comparisons, results are statistically significant at p=<.005.

One Seattle teacher explains that science is not her strong suit but that the Science-Writing Program enables her to value, and even like, teaching science.

> I do not have a science background. It hasn't been something that I had loved and enjoyed as a child and through college. So for me this program made it possible for me to become a teacher who loved and saw the value in teaching science because I was so supported in it. If I had been left to my own devices, I don't really know what I would have done. *5th grade teacher*

Teachers outside of Seattle echo this finding. A fifth grade teacher who piloted the program in 2008–10 says that the Science-Writing Approach helps her teach science better.[10]

> Levers and Pulleys is not as much my strength… [Science-Writing Approach] really helps me focus the purpose of my lesson and the overall concept if I am asking them to write about it and I am looking for a strategy specific to help them gain that scientific understanding. I feel like when I use the notebook… I feel better prepared for the lessons and that my students get more out of it.

Teachers in Seattle and elsewhere find that this approach to writing also improves their ability to assess student learning and monitor their own teaching. Students' science writing shows teachers the extent to which students understand concepts, and it informs teachers' teaching:

> They can actually communicate through writing what they have learned and it clears up misconceptions as well, because I know right away whether they have understood it, or they didn't, and so I can jump right back in, redo the experiment, and do whatever I have to do to make sure that their misconceptions are cleared up. *2nd grade national teacher*

> The more I used science notebooks, the more I felt that it helped, one with their understanding and, two, with my understanding of whether or not they were understanding the concepts being taught. *5th grade national teacher*

> The writing helps in my assessment of kids' learning and whether they are really grasping the concepts, because they have to express themselves and answer the focus questions, which gives you an idea of what they have really understood in the lesson. You can have a class discussion, but sometimes it is hard to monitor and figure out who in the class has that conceptual understanding. *3rd grade Seattle teacher*

- **Science-Writing Approach strategies translate from science and apply to other subjects as well.**

The payoff of science writing reaches beyond science because teachers find that the strategies translate quite naturally to other subject areas, offering students similar opportunities to express their reasoning across the curriculum. Teachers in Seattle say that how students approach learning through writing in their science notebooks supports their skill development and inclination toward evidence-based reasoning, not just in science but in other subjects too.

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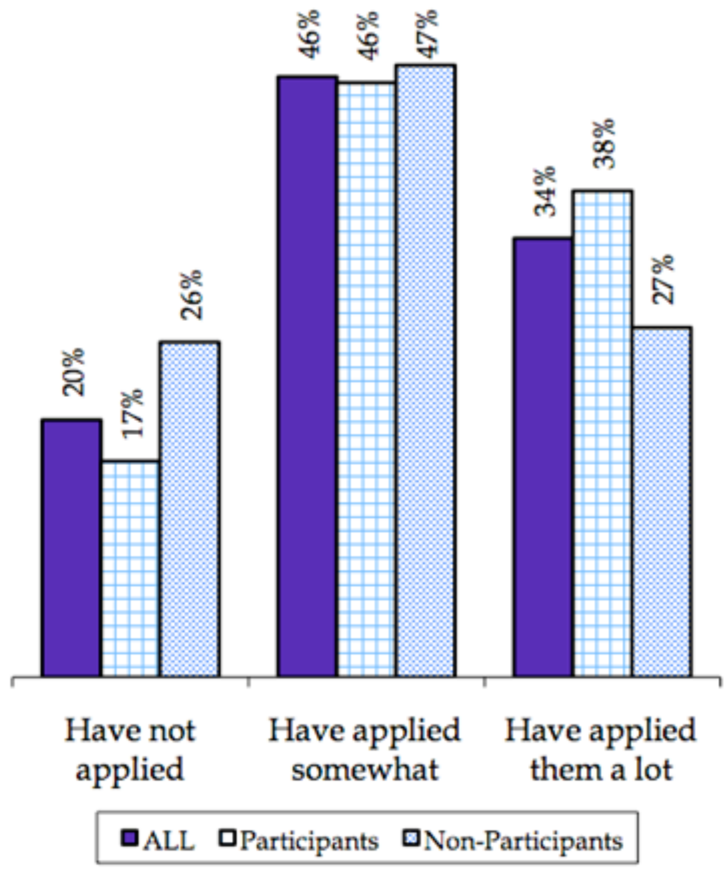
10 Inverness conducted interviews with a sample of the pilot teachers in Fall 2011 to learn the extent to which they had continued to use the approach and how they might have developed since they completed their participation in the piloting of the new materials designed to support implementation outside Seattle.

> It is helping them with their expository writing across the board, because in social studies, math, other areas of the curriculum, they are getting more practice in writing expository. You see them using transition words and the frame structures in other subject areas, it carries over. They use more deductive reasoning, too, like for example, in social studies we do a 'mystery country' activity where kids get certain clues, and when the kids are in the discussion, they will automatically say, 'well I think it is Japan because this, and this, and this.' They provide the evidence, which we force them to do in a science notebook. I think the reasoning just naturally carries over into the other content areas. *3rd grade Seattle teacher*

And it is the teachers who have a better grounding in the Science-Writing Program who are more likely to apply the approach more often in other subjects as Figure 2 shows.

Figure 2. Extent to which teachers have applied writing approaches learned from science-writing classes to other subject areas[11] (percentage of teachers reporting)



The difference between the two groups in "applied them a lot" is statistically significant at p=.043.

- **Independent panels of science education experts find that the Science-Writing Program helps Seattle teachers improve their science teaching**

In order to "test out" Seattle's perception of the benefits to teachers and students of the Science-Writing Program with an audience external to Seattle, Inverness' 2003 study asked a panel of outside experts—teachers, administrators, curriculum specialists, scientists—who were knowledgeable in science and literacy reform to review student notebooks of Seattle teachers, share what they saw, and identify what evidence of the program they saw in teachers' teaching through the lens of student work. The outside reviewers found that the Seattle student notebooks

[11] For purposes of brevity, we use the term "non-participant" in the legend for each graph in this report. This group is more accurately described as "non/limited participants" because some have experienced one workshop.

showed evidence of a systematic approach to teaching in which writing improves students' learning of science concepts and skills, and in which science serves as a fertile context for the development of writing.

By reading a sample of several student notebooks from Seattle teachers' classes, independent reviewers could infer the presence of a systematic professional development program that enables teachers to improve their teaching of the science units to the extent that the resulting student work is distinctively better than work they have seen elsewhere. They emphasized that student work such as what they were seeing in these notebooks does not happen by chance. Two external reviewers commented:

> [In the student notebooks, I saw] a gamut of abilities that I think definitely exceeded my expectations. It was clear, even in the structure where the student will have circled the appropriate word to concentrate on in the focus questions, that the teachers had undergone special professional development, and so [this work] is not something that I would expect to see in other classrooms, outside of Seattle.
>
> It is clear that the work of the teacher shines through this—that is not something that [happens] spontaneously when you just work with a science kit, or just pass out the notebook with the kit.

The occasional notebooks that lacked strong student writing stood out as a contrast, again causing reviewers to infer the presence of specific teaching practices in the great majority of the notebooks:

> In certain notebooks you could tell, they were asking questions about pollination, and the kid answered it, and in other notebooks, the teacher didn't ask that and the kids didn't mention that at all. I noticed that it really depends on what questions [the teacher asks].

Multiple studies find that science-writing teachers in Seattle teach more and better science with more confidence than their peers who use the Science-Writing Approach less or not at all. Independent reviewers' assessments of Seattle student science writing generally concur with teachers' own assessments, finding that the Science-Writing Approach helps improve science teaching. Teachers outside of Seattle express benefits similar to those of the Seattle teachers.

CLAIM 2: The Science-Writing Approach improves learning for a wide range of students

Teachers are teaching science better only if students are learning science better. In other words, the real test of the approach is its impact on student learning. The substantial evidence in this section supports the claim that science writing enhances students' science learning, teaches them expository writing, and holds potential for meeting the learning needs of a wide range of student abilities in a classroom.

- **The Science-Writing Approach helps students move from hands-on investigation to concept development**

One of the great challenges of "hands-on" science teaching is to facilitate students' interactions with materials in such a way that students actually develop both their scientific skills and conceptual understanding. A general finding from our studies of the Science-Writing Program is that the approach to teaching writing, in conjunction with hands-on inquiry-based science curriculum, helps teachers engage students in purposeful investigations and to use writing to link investigations to conceptual sense-making.

The perspectives of teachers on the Seattle program

A great many Seattle teachers responding to open-ended questions in our survey report that writing in science helps students make meaning from their experiments. Several representative comments:

> It helps students construct their own meanings from their own experiments and data. It proves/disproves what they truly understand about science concepts. A child can observe and conduct an experiment and still not really understand the results.

> It causes students to reflect on the new information or continue to organize what they've learned.

> [It] allows kids time to mentally process a science concept.

> Students make connections from experiments to concepts.

One third-grade teacher in Seattle explains in an interview how science-writing strategies strengthen students' ability to think and write clearly about science concepts:

> To write about the concepts they have to think about them. That is the whole idea—that the writing has to come from their thinking. If they didn't have to actually write out how you can make a long string have a high pitch, they may never have really thought about that. It forces them to think about the concepts in science.

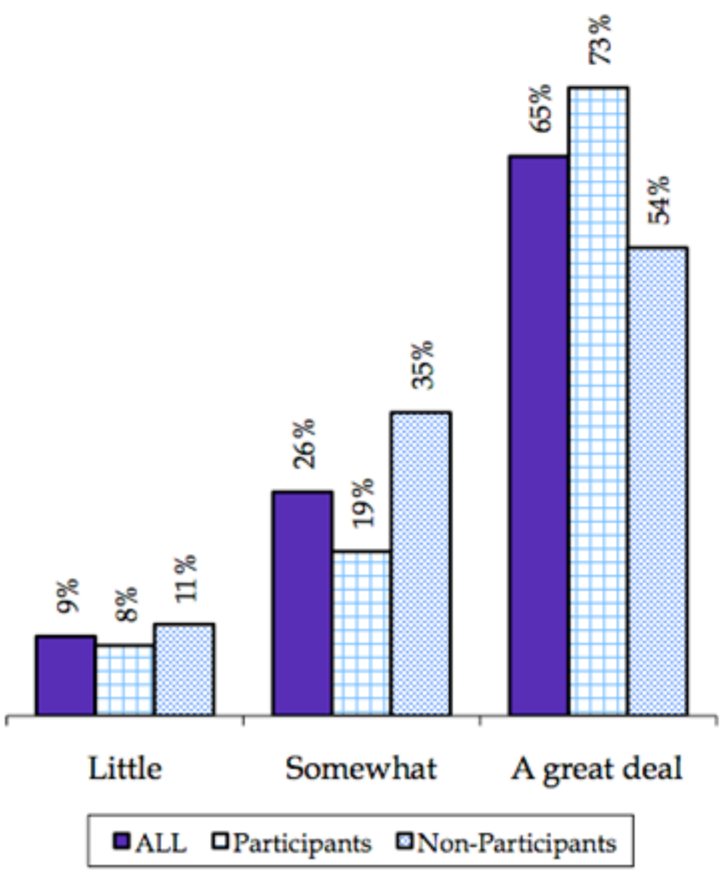
Seattle teachers also report that the cumulative development across the year, which the program affords, is valuable to student learning. Two comments from surveys in Seattle:

> In 1st grade, the quality/skill level is dramatically different at the beginning than the end of the year…it's a little hard to get quality science writing at the beginning of the year, but if students do participate in science writing routinely, their overall writing skills improve much more dramatically than if they hadn't done science writing at all!!

> My students love their notebooks. They take great pride in their writing. They show so much growth!

Seattle teachers' impressions of the benefits to students seem to accrue with more use of the program. The graph below shows that 73% of teacher participants in the Science- Writing Program in Seattle said the approach strengthens science learning "a great deal" for their students compared to 54% of non-participants.

Figure 3. Contribution of writing to student learning in science (percentage of teachers reporting)



The perspectives of independent outside reviewers of Seattle science writing

Independent reviewers corroborate the finding that science writing helps students move from hands-on investigation to science concept development, and place the finding in a broader educational context. They judge that student work from Science-Writing classrooms is, on the whole, more sophisticated in quality, and reflective of greater rigor and a higher level of learning of both science and writing, than is typical in science programs in other schools and districts that use similar science units.

Based on the Seattle student work they read, external reviewers note that students are learning science concepts and skills and learning to write in deeply engaging ways that reflect the rigor of science as a discipline (Stokes, et al., 2005: ii). Representative comments from two reviewers:

> They [the students] took everything, they took the good frameworks for the writing, they took the knowledge that they had, the scientific concepts, and then they added their own understanding.
>
> There is also a lot of opportunity in the context of those notebooks for analysis and synthesis and so, through the writing that requires you to do that, you are having to really think deeply about the science, and dig a little deeper into the concepts than you might otherwise do.

The reviewers note, as classroom teachers do, that the writing approach compels students to examine carefully and make meaning of the data they have collected from an experiment. One reviewer, a high school teacher of science, observes this in a fifth grade notebook, and notes that it is an often-neglected skill:

> There was an opportunity for them to table information and then they actually sat down and discussed that table in a piece of writing text, and so they have that reinforcement of the learning. They really clearly followed all of the different elements that had been laid out in the table. Working with the high school students, often times they would collect the data and put it in a tabular form, but then they would neglect to actually have a discussion about it, so to see 5th graders doing that is really encouraging. You don't make the table just to tack on the wall somewhere, but it is a place for you to begin your review of the evidence, to link it all together and be coherent.

The reviewers comment that students' use of a variety of data gathering and portrayal techniques (drawings, diagrams, graphs, matrices) enhance both the writing and the conceptual development in science. They note considerable evidence in the notebooks of students' purposeful use of the skills of scientific study and development of scientific thinking.[12] About the notebook excerpt below from a third grade student, a reviewer observes that the combination of an illustration, a "sophisticated cut-away view of a straw," together with the written explanation, shows "advancement of cognitive development":

> How does the length of the vibrating air column affect pitch?[13]
>
> [This is followed by a cut-away side view illustration of a straw with three holes in it. The reed, holes, straw, and the path of the air are labeled.]

---

[12] All excerpts from student notebooks are from Seattle.
[13] All indented and italicized passages in this format are verbatim quotations from student notebooks.

> My straw was short and had a high pitch when I didn't cover any holes and made a
>
> meadium/high pitch when I covered the first hold and on the middle and last hole mad a medium/low pitch. My straw vibrated very fast when I didn't cover any holes *(Stokes, et al., 2005: 36).*

Another reviewer remarks that the following excerpt from a first grade notebook is "one heck of a great example" of scientific understanding and expository writing evolving hand in hand:

> Focus Question: Wich balls were the best bouncers?
>
> We tested the "bounciness" of balls by using a ruller, and one of us droping the ball the othr prson measurd how hi it bounced in inchs, we also countd how meany inchs itbounced.
>
> The "bounciest" balls were the pink rubber ball, the tennis ball, the sm. Polsture [polystyrene], the sm. glass ball, and the ping pong ball.
>
> The least bouncy bll were the sm. wooden, the lg wiffle, and the lg polysture. The propties that good bouncer share are the size small, and big and texter fuzzy, and smooth. The best bouncers were made of rubber, fuz, styrofoam, gass, and plastic. Wood dos not make a good bouncer *(Stokes, et al., 2005: 36-37).*

A fifth grader's notebook that exhibits deep engagement in the extended sequence of data gathering and documentation, hands-on experiments with different conditions, and writing for the comparison of three stream tables "impressed" a reviewer. She notes that

> [students] were expected to use numerical data, observational data, and diagrams to make comparisons. The diagrams were colored and labeled, and written observational data could be compared against them…I think all of this is so important because the student is using many different kinds of scientific processes to compare conditions….is answering questions, supporting assertions with evidence (such as, I think this happened because…). The evidence is data collected during the activity.

Outside reviewers also observe cumulative development of conceptual understanding occurring over time, as the progression of writing experiences followed the scientific investigations in the unit. One reviewer comments:

> It seemed like in a number of them, if they didn't get something at first, or they are a little confused or the notebook was empty at first, it seemed like by March they were getting it, understanding more.

Reviewers note that students are learning the habits of mind of a scientist by referring back to the cumulative record in their notebooks to predict the result of a test based on past investigations and to state whether data confirmed the prediction or not. Commenting on a fifth grader's investigation of how hills affect the flow of streams, a reviewer says that the "student demonstrates a sense of self as a good observer and participant in scientific investigation, a sense born out of the work that precedes this page." For this lesson, the student had written:

> I predict the large hill will get water on it and at the end I think the hill will give way because the water will pile until it has enough power.

Then, following several entries devoted to specifying the "manipulated" and "controlled" variables, the materials needed for the experiment, and a drawing of the resulting stream movement in relation to the hill, the student wrote:

> This data does not support my prediction because I observed that instead of hacing [having] the water make the hill give way it went right around the hill and the hill didn't get very wet.
>
> In conclution I think that a hill does effect the flow of the stream.

Some reviewers note that students developed facility with scientific vocabulary, both conceptual and descriptive. One says, "I saw this as a general pattern across [notebooks]." Remarking about the excerpt below from a first grade notebook in which the student was asked to describe the properties of different balls, a reviewer says, "There is evidence that students understand the concept of 'properties' and that they are using all senses to describe them, not just visual":

> boom boomnoise
>
> pink
>
> sphere
>
> soft (Stokes, et al., 2005: 36-37).

As much as the field experts were often pleased to see the scaffolding that guided students' thinking (e.g., carefully worded questions, attention to transition words), they were especially impressed whenever they read entries that seemed to stem entirely from the students' own sense of what was important. For example, a reviewer calls the following excerpt "awesome, honest writing. The student didn't get what they expected, but understands the nature of science. You still need to write about what you discovered":

> [Vocal cord experiment] When I blew into the thiner for the first time I got nothing then I blew again I got a low pitch, so I figured that I wanted to write about it because it could be important *(Stokes, et al., 2005: 31-33)*.

Evidence from student work outside of Seattle

Teachers piloting the approach outside of Seattle make observations similar to those of Seattle teachers. Two comments from fourth-grade teachers:

> I knew that the Science-Writing Approach] was going to be useful, but I don't think that I could have anticipated how helpful it has been in deepening and furthering and focusing kids' thinking. I really have seen a big improvement in the kind of science inquiry skills that children are showing me now, since I started using the materials and asking them to do a more focused writing.
>
> Predictions are better, data collection is better. Kids are taking data collection much more seriously. You walk around my classroom now and it is not just one group or two groups that are carefully measuring and recording data, everybody is doing it.

Seeing evidence of the benefits of the program in Seattle and hearing from pilot teachers outside of Seattle compelled us to ask about the extent to which the program's benefits extended to students in classrooms outside of Seattle where pilot teachers were using only the *Writing in Science* book without the professional development and curricular supports that Seattle teachers had.[14] In Summer 2009, Inverness took a preliminary look at student notebooks in the classrooms of teachers at three different sites in two states where teachers were in their second year of piloting science writing materials and meeting in study groups.[15] The question we asked of the notebooks was, what evidence do we see of Science-Writing strategies, and what impact do they appear to have on student learning in science and expository writing?

Notebooks where there is evidence of a strong science foundation and at least fairly thoughtful use of the writing strategies-even if it is only one or two strategies—show evidence that the strategies from the science-writing materials strengthen the students' ability to think and write clearly about the science concepts. For example, a student's use of "because":

> I think the water will go faster. My prediction was correct. The water went faster because it is more fluid. The oil is more visous [viscous]. *1st grade student*

And a student's use of the stem, "I observed… therefore I know":

[14] As a reminder, in Seattle, teachers can participate in 7.5 hours of science-writing workshops where they also receive unit-specific science-writing curriculum. In addition, some of these participants are chosen to join the Lead Science Writing Teachers (LSWT) team. The LSWTs field-test curriculum, provide feedback for developing science-writing classes and support materials, mentor new LSWTs, and, in some cases, go through an apprenticeship in which they ultimately provide professional development in the science program.

[15] We read 69 notebooks, three from each of 23 teachers. The teachers selected a low, medium, and high notebook for their class sample.

> I observed that when we put the vail [vial] in the room temperature water the red hot water went to the top therefore I know the red water is less dense it floats. *3rd grade student*

The value of the Science-Writing Program to student learning and teachers' teaching is meaningful in part because it is exactly what the science education improvement community is looking for but rarely finds. When used reflectively and thoughtfully, science writing can enhance what is offered in science units. In fact, the writing component can take the lead in augmenting students' science learning experiences.

- **The Science-Writing Approach helps students learn to do expository writing**

Expository writing is an important, and often neglected, area for students' literacy development in elementary school. Hands-on, investigation-based science is a fertile context for the teaching and learning of expository writing because the writing fosters thinking about and internalization of concepts through language; the science experience generates important, compelling content about which to write.

Independent reviewers of student notebooks, principals outside of Seattle who have come to know the program, and classroom teachers who use the approach with their students speak out about the importance of explanatory and analytic writing as a part of students' repertoires, beyond the narrative forms more typically taught in elementary grades. A principal outside of Seattle who is supporting the teachers in his building in their implementation of the Science-Writing Approach says:

> I think the formalization [of science writing] is giving the teachers the guidance that they need and the [understanding] that it doesn't need to be what we would call literature writing, but it is science content writing and it looks different… That is the piece that we were looking for, because we know that it is advertised everywhere and it is written too in many articles that you read that if you want to increase reading scores in your school, it is through non-fiction writing because children will do more non-fiction writing as they become adults than they will do anything else.

Below are comments from two independent external reviewers about the value of teaching expository writing, in addition to narrative and fiction, in elementary science:

> I think from age 0 to 10 they are into narrative type stuff, but as kids get older from 10 to 20, you are moving so much more into expository type, persuasive type of writing and writing letters. Think of your university—they ask the kids, "Can you explain to us why you think you should attend the UW?" Not that I would ever want to say to a fifth grader, "You are going to have to use this when you apply to college," but if you don't start it there, they don't have the foundation. The majority of what you do as an adult is that type of writing. I don't know the last time I wrote a story.

> I have seen other writing approaches where the assignment would be something like "Pretend you are a sow bug in your terrarium, describe your day," or something like that. That is so different than what we are asking, that's more of a fictional write. What we are asking them to do is really deep, and it is hard to learn to do it well. Pretending you are a sow bug in a terrarium would be easier to deal with than to figure out, you know, "I notice that the sow bugs are doing this and my evidence is that, and therefore I think this." And that is my goal, to get them being able to do that, to see what evidence really means. If my student says "I believe that the sow bug is half-shedded," well what is her evidence? And she can write it in there—"because half of it is cloudy white and half of it is black." That is the kind of thing I am going for.

Teachers involved with the Seattle program say that science writing offers a valuable alternative to a writing curriculum that asks students to draw primarily from their imagination or personal memories. The concrete phenomena and immediate experiences of hands-on science give students meaningful content to write about:

> I like teaching the writing in conjunction with the science curriculum because it makes the writing meaningful for the children. In my first year, I didn't have all of this training in the writing and I really didn't know how to go about teaching the writing. I had them write in their journals and write stories, but they didn't get into it as much because it wasn't meaningful. Playing with these balls and bouncing them was something they were experiencing firsthand. They have just done the bouncing, so they can go back and read what they observed, and write about it right away. *1st grade teacher*

> For some kids writing from something concrete in front of them is a more powerful place than to tell them 'use your imagination.' Certainly there are children who are wonderful at creating amazing stories, but I have found that kids who really struggle with writing all of a sudden have the ability to do more because they just had this experience that happened five or ten minutes ago, and they can connect with that, right there. *5th grade teacher*

> A lot of writing kids do in school is, I hate to say it, meaningless to kids, where they just read about something and regurgitate it. But this is real—this is something they are doing, something they are touching, this is something that they are understanding from their own observations. *3rd grade teacher*

Students often resist writing, whether in science or other subject areas, because they do not know what to write about, their thinking is unclear, and they cannot put it into words. Teachers piloting the approach nationally report that science investigations give students the content for their writing, which eliminates a piece of the struggle. One teacher said this:

> Since I started using [the Science-Writing Approach], I have not had a student say to me, 'I don't know what to write about.' They have experienced it, and it is hands-on, and it is right there. They have seen it, they have touched it and they

> have smelled it and they have done everything they can with it and so their writing just flows. *2nd grade national*

A first grade teacher from outside Seattle said her students' focus shifted from counting the number of sentences they had to write to willingly explaining their thinking in writing:

> I see they are more excited to try and explain something to me, whereas at the beginning of the year, the students [asked], 'How many sentences do I have to write?' [Now] when we get in science, they understand that they need to explain and write until they have gotten it to where I understand it.

Another national pilot teacher explained the strength and value of the Science-Writing Approach, in which oral processing of an investigation precedes written language development:

> Even when you talk to the kids, they are using the frames and the phrases in their conversation and so because they can say it, they can write it so much better. The fact that they can explain themselves and explain what they have done in a high level way, I believe is the reason for our high scores [on standardized tests].

Not only do teachers value the writing students do in their science notebooks, but students do too. One national pilot teacher said that the pride that students show in their science notebooks is unparalleled among classroom artifacts because the notebooks are filled with their own writing and thinking:

> I can't tell you the sense of pride that the kids take in it. When I have parent teacher conferences, almost every student that I have, when I ask them to pick up something that they were wanting to show their parents were proud of, like 99% of the kids said I want to show my notebook. For the majority of it, it is 100% student written and by the time we finished it, they used up almost a whole notebook and I model it and so even my messy kids have a nice, neat notebook and they just feel a sense of pride and look at all of the writing I did, look at what I said, and look at what I thought and it is organized in a way that makes sense and to them it looks like a true science notebook. *5th grade teacher*

Similarly, Seattle teachers' survey comments about science and writing highlighted that the writing approaches seem to engage students more deeply and enthusiastically in their scientific work:

> [It] engages kids more deeply and meaningfully in the science activities/skills/and learning.
>
> Students think of themselves as real scientists! Just like scientists, they are observing, recording, and analyzing. They think this is pretty neat!

• **The Science-Writing Approach holds potential for "leveling the playing field" for different student populations**

The nation's teachers face the tall order of providing all students in a class—form those with special needs to the highest achievers—with equal opportunities to learn. Evidence suggests that, when fully implemented, the Science-Writing Approach has potential to do that. Inverness' two in-depth studies of student writing in science notebooks in Seattle both suggest that the program has potential for contributing to more equitable achievement for learners with special needs (Stokes, et al., 2002, 2003). Independent reviewers judge the approach as being especially effective in supporting the learning and language development of ELL students and others struggling with literacy in English. The approach quite naturally offers differentiated, accessible opportunities to a wide range of students for understanding and expressing their thinking about science content learned through investigation.

Science writing and the achievement gap

We analyzed student science notebook scores[16] assigned by reviewers against student demographics in 13 Seattle elementary schools to see whether notebooks scores would follow the predicted trend of lower science notebook scores in schools with higher populations of at-risk students. The expected pattern occurred in most schools; however, a cluster of five schools had higher-than-average representation of both ELL and poverty level populations but their science notebook scores ranged between 7.4 and 9.0, less than one point difference from the overall average of 8.3. This pattern suggests that in these schools, at-risk students had experiences in science that promoted high-level science learning and expository writing. This departure from the pattern is provocative because it shows potential for a "leveling of the playing field" in schools with at-risk student populations.

We display these results in the two graphs below. We have circled the points for the five trend-breaking schools.

[16] The rubric measured three dimensions—scientific thinking, science concepts, and expository writing—using a 4-point scale for each, for a total possible notebook score of 12. See Stokes, et al., 2002 and 2003 for details on the methods and analytic scoring rubric used for this study.

Figure 4. Total notebook scores compared to % of students qualifying for free or reduced lunch

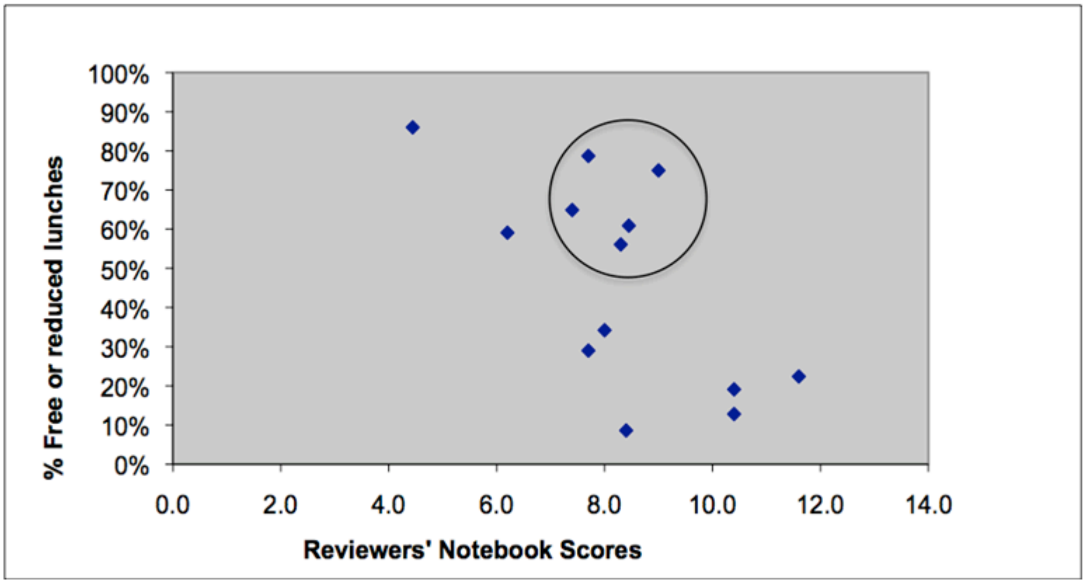
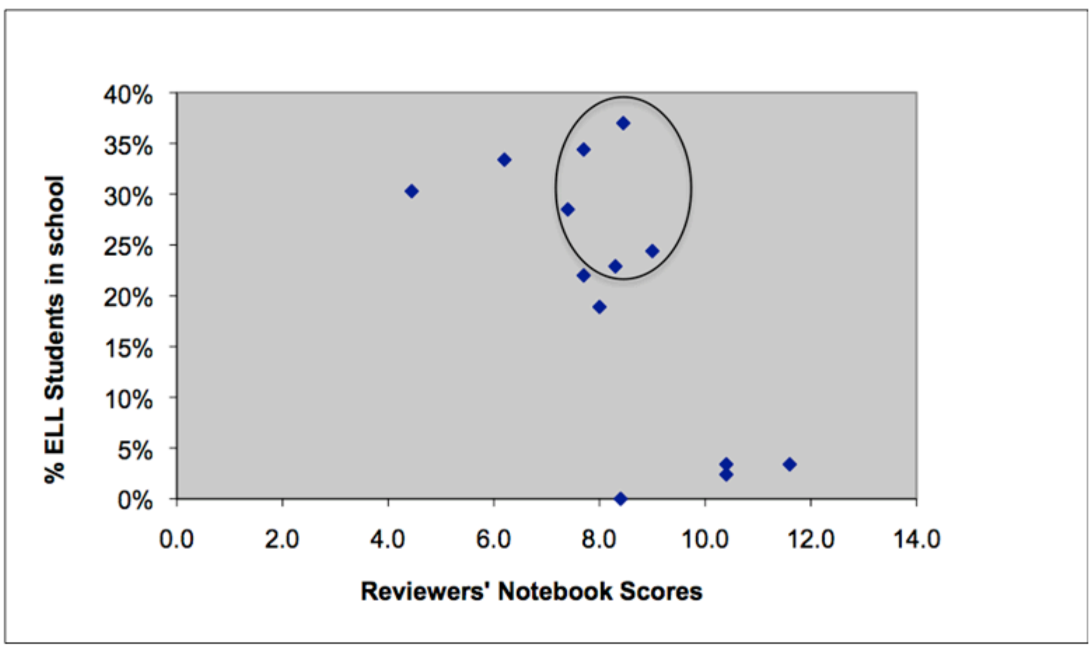


Figure 5. Total notebook scores compared to % of ELL students in school



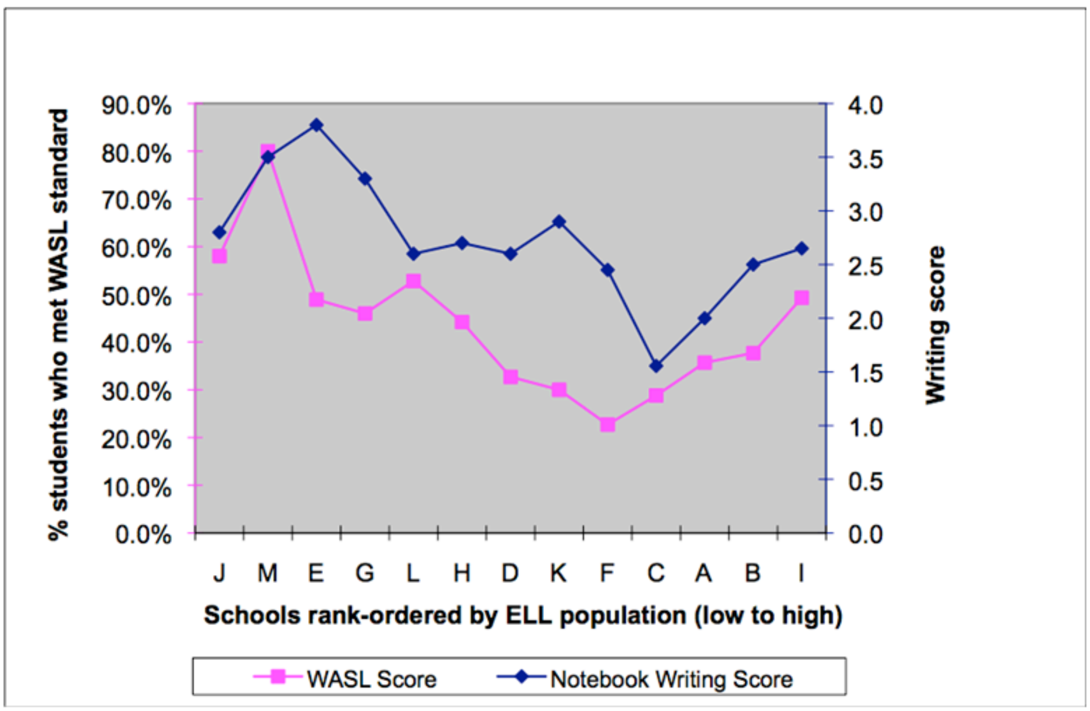
We also investigated what relationships there were between scores on the Washington Assessment of Student Learning (WASL) in Writing and notebook writing scores for the five trend-breaking schools we refer to above.[17] On the

[17] We used the Expository Writing score for the science notebooks; writing scores could range from 0-4.

graphs below, these five schools are identified as B, D, F, I, and K. We compare notebook ratings on the 4-point-scaled Expository Writing criterion for the notebook study against 4th grade WASL writing scores for the 15 sample schools, again by the two demographic characteristics of ELL concentration and poverty rates.

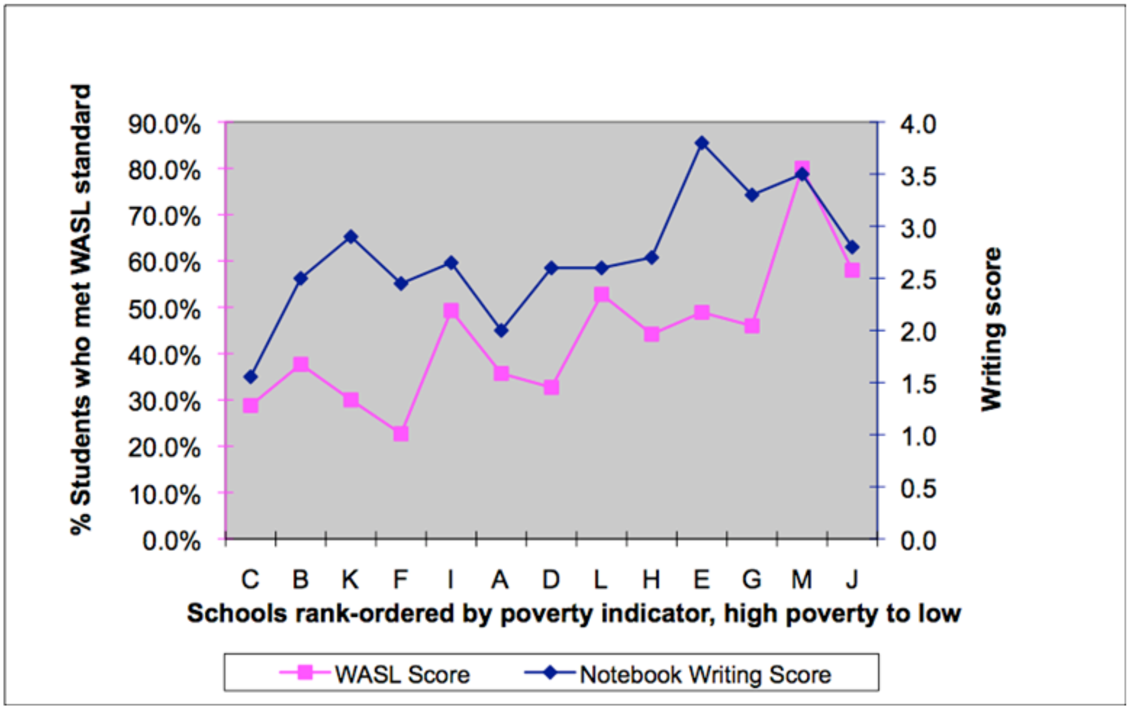
The graph below compares the Expository Writing scores to WASL Writing scores in schools rank-ordered by ELL population. We observed that both WASL scores and notebook ratings show a rough trend toward lower scores in schools with higher ELL concentration and poverty levels, though there are individual schools in this sample that counter that trend. In three of the five trend-breaking schools described above—D,K, and F—notebook scores show a greater tendency than WASL scores to counter this trend; that is, there is a weaker relationship between notebook writing scores and school ELL and poverty.

Figure 6. 4th grade Writing WASL scores 2000-01: % who met standards by school ELL status compared to expository writing scores on science notebooks



Similarly, the graph below compares WASL scores and Expository writing scores in science notebooks for schools ranked by the free or reduced lunch poverty indicator. Both curves show a similar rough trend toward higher scores in schools with higher wealth. However, there are sizable gaps between notebook ratings and WASL scores for four of the five schools of interest where there are substantial proportions of high-poverty students: B, K, F, and D. This shows that for these four schools there is a weaker relationship between wealth and scores for the notebook ratings than for the WASL scores.

Figure 7. 4th grade Writing WASL scores 2000-01: % who met standards by school poverty status compared to expository writing scores on science notebooks



Together, these breaks in pattern suggest that the notebook program offers students opportunities for growth in writing that may have potential to contribute to a narrowing of the gap between "at risk" and more advantaged groups.

Teachers' perspectives on the power of science writing for students

The teachers have especially strong beliefs about the power of the Science-Writing Approach to support the learning of students who, for a wide range of reasons, find it a struggle to use written language. They may be first graders just learning to write, English Language Learners, students with learning disabilities, or students with such under-developed motor skills that they resist writing. The teachers believe that the Science-Writing Approach helps these students develop the skills and confidence they need to participate and communicate alongside their peers. Comments from a range of teachers:

> It really helps those kids who just don't know where to start, maybe they are ESL or Special Ed. Some of my more advanced students, if I ask a question, will automatically know how to get started, but the kids who don't will just sit there. If they didn't have that frame or if they didn't have the modeling, they wouldn't be very successful at all. It gives kids who don't have the ability to write, that voice. *3rd grade Seattle teacher*

> I think it gives kids power, it opens up possibilities for them, they can express themselves. You know that life is getting better for Special Ed or ESL kids

> when they come to you with their science notebook to say, 'Look at what I just wrote.' *5th grade Seattle teacher*

> Within the first few weeks of me teaching my first science unit, I was able to go to one of Betsy's classes and she started introducing the frames. I thought, 'Well I don't know what I feel about frames, because aren't they supposed to be thinking independently?' But I was overwhelmed and new to the science curriculum, and I had a high level of bilingual kids, so I began to use the frames. What was amazing to me is that my students felt so much more comfortable expressing themselves that way. I even pulled it over into math, and for my students, their math writing shot way up, from struggling to get them to write a sentence, they were suddenly able to write an entire process of how they solved a problem. *4th grade Seattle teacher*

> For the ones that who aren't good at reading or writing, this is engaging them and making them excited. Then they find out 'I can do this!' and then there is a snowball effect and they keep trying. I've noticed kids lately, when they have some extra time, they will go back and read their science notebooks, because they think it is fun. It is powerful. *1st grade Seattle teacher*

Teachers outside of Seattle also find this to be true. They see science writing holds potential for helping special needs students succeed:

> When I look at some of the pre-made notebooks that people have come up with, there is so much writing already on the page that [for] my struggling readers and my struggling writers, that is overwhelming. I have one little guy that can't write in a confined space. If you give him a little box, he has a hard time fitting all of his letters in. So what I like about [the Science-Writing Approach], I think it allows every kid to have what amount of space or whatever structure that is best for them, and it meets all of their needs versus a pre-made chart… I think it helps them a lot just for that reason because it is their own and there is a range of what they look like. *2nd/3rd grade national pilot teacher*

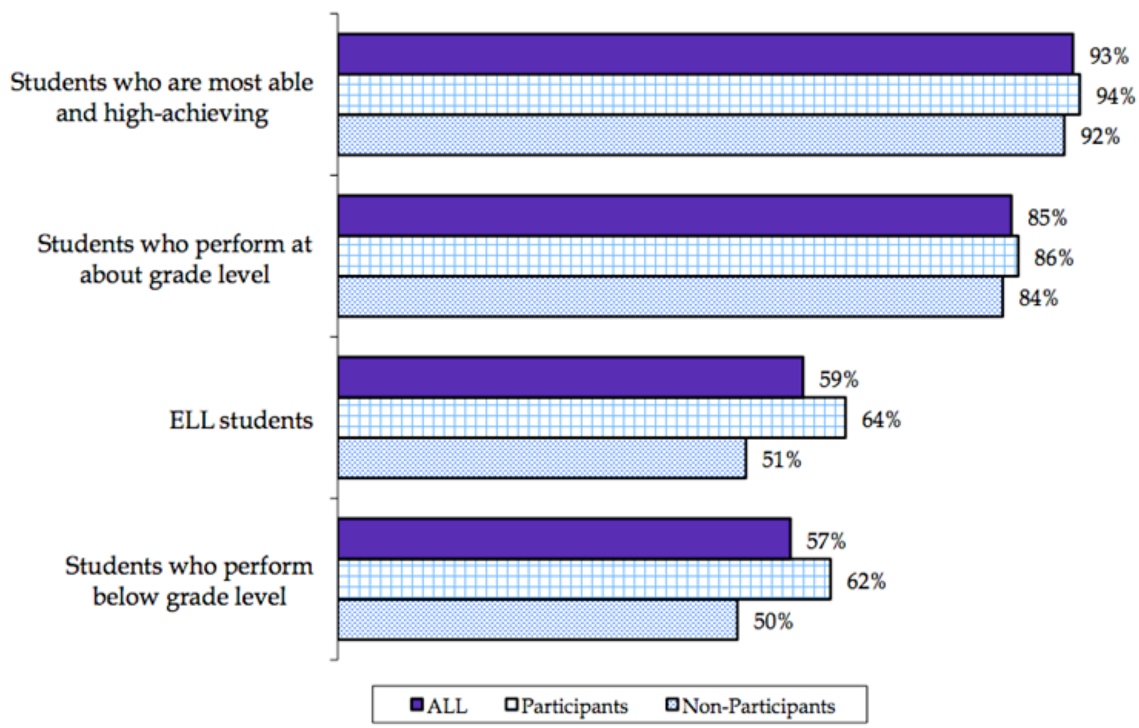
> I am having [students] talk more with each other, which has helped my lower ones improve their vocabulary choice… I will tell them talk to your teammates and…it helps them to say how would you describe it, fuzzy or soft or anything that they need to. I see more growth out of my low kids, but they also have the most to grow. *5th grade national pilot teacher*

Changing teacher expectations for student performance

Based on participating teachers' and independent reviewers' comments on the effectiveness of these strategies, we can infer that teachers involved in the program may have developed higher expectations for ELL students and students below grade level by using the approach and by observing that it supports the learning of these students. In Seattle, the great majority of participating teachers and non/limited-participants alike report that writing is helpful for students who are at or above grade level. However, Science-Writing Program participants are more likely than non/limited-participants to report that writing is helpful to ELL students and students who are working below grade level.

The graph below shows that, among Science-Writing Program participants, 64% believe writing helps ELL students, compared to 51% of non/limited-participants. Also, 62% of participants believe writing is helpful to low-performing students, compared to 50% of non/limited-participants.

Figure 8. Percentage of teachers reporting that writing in science is helpful for particular groups of students



Percentages represent teachers who marked "4" or "5" on a 5-point scale where "1" = "not at all helpful" and "5" = "very helpful." The result for ELL students is statistically significant at p=.03.

The implication is that the more experience a teacher has with the Science-Writing Approach, the more likely she is to believe that writing is helpful not only to the most able, high-achieving students, but also to low-performing and special needs students. This is an important finding because low-achieving and special needs students too frequently receive short shrift in writing instruction because of their more deliberate work pace and the demands placed on the teacher to move them forward. This pattern presents yet another strong argument in favor of supporting teachers' growth in understanding and use of the Science-Writing Approach.

Independent science education experts observe that the approach supports language development

Independent reviewers also see considerable evidence that the approach gives ELL students and others who are struggling with language development—especially younger students—a valuable springboard into written English and an important scaffold of language and logic on which to build their learning of science (Stokes, et al., 2002). They note:

> A number of notebooks were clearly from kids that weren't speaking English well at all. They might start out their notebook barely able to put a sentence together because of the language issue, and by the end, they were much better able to do writing. They were learning to write, learning to communicate in the context of doing science.
>
> They are being given a structure that allows them to learn a language that is not their first language, and to demonstrate what it is that they know and learn in science.
>
> Kids don't walk in being able to think and record and write in logical step-by-step-by-step ways. They don't come knowing that there are signal words, or knowing there are transition words, or knowing that you are necessarily supposed to do your evidence and then draw your conclusions from your evidence. That needs to be taught.

The independent raters see that these students are able to provide teachers with evidence of their learning in science through their writing, which they could not have done without access to the language and structures provided in science writing. This in turn seems to afford the teacher better means of assessing student understanding:

> The child is not ready to generate the sentences in English but they can follow the model. And since they have done the science experiment and they are filling in the data, it allows the teacher to see what the child knows from having done the experiment, rather than for the teacher to see what the child can't do. We know this kid can't do this independently, so why put a writing task before them that is going to frustrate them and probably make them feel badly and perhaps not want to do science. At the same time, it is teaching the structure of the language and the protocol for this kind of thinking and writing (Stokes, et al., 2002: 38).

- **The Science-Writing Approach shows potential for improving test scores and meeting standards**

The bulk of evidence discussed thus far suggests that hands-on science and science writing can create powerful learning experiences for students. This in itself justifies more widespread use of the Science-Writing Approach. But a standards-driven system in which national success is measured by standardized test scores raises the question of whether and to what extent the approach addresses standards and prepares students to succeed on tests. We gathered data in 2003 to answer this question.

Impact on Washington Assessment of Student Learning Science scores

In 2004-5, researchers from the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) conducted a pilot study of correlations between fifth grade Washington Assessment of Student Learning (WASL) Science scores and teachers' participation in the Science-Writing Approach (Choi and Herman, 2005). The researchers found that students of teachers who participated in 7.5 hours or more of the Science-Writing Approach professional development within a 3 year period outperformed students of non- and limited-participating teachers (less than 7.5 hours) on the fifth grade Science WASL by an average of 8 points. Moreover, the CRESST study found that Grade 5 science test scores were higher for students who were taught at Grade 4 by science writing participants than those who were taught by non- or limited participants. This "prior year effect" was more pronounced in low SES classrooms than high SES classrooms. And more broadly, Seattle Public School students out-performed other Washington districts on the fifth grade science WASL, taking into account SES status.

The perspectives of independent reviewers

In our 2003 study, independent reviewers in Seattle note that the evidence they see of the program in student science notebooks is consistent with Washington State science standards at the time and appears to help students address and meet several standards (Stokes, et al., 2003):[18]

What these kids are doing is exactly what we want them to be doing in the state of Washington.

The curriculum is appropriate and aimed at both the essential learning and the kinds of ways of demonstrating knowledge that we are interested in, and I think it is exactly what we want.

> And then with scientific thinking and science being sort of the third standard, I think these notebooks provide a lot of evidence [of students] thinking about their observation, interpreting data, descriptive writing, all of that is very evident. So it is very standards-based as far as science.

An out-of-state reviewer notes that the work is also consistent with other state standards, especially for expository writing development. These reviewers explicitly note that it is the combination of writing and science that helps students meet standards:

[18] The standards and assessments referenced in this section were current in Washington State in 2003 and are currently being phased out and replaced by different standards and assessments.

> They are having a lot of opportunity to meet both science and writing standards.

Reviewers comment that the types of prompts used to frame science investigations are likely to prepare students to be able to respond to a range of on-demand writing assessments in science.

The perspectives of teachers and principals

In a survey Inverness Research administered to several hundred Seattle teachers in 2003, 78% reported that writing approaches they had learned in the Science-Writing Approach professional development classes helped them prepare students for the WASL Science assessment, and 72% reported the approaches helped them prepare students for WASL writing assessment (Stokes, et al., 2003).

Outside of Seattle, the Science-Writing Approach is being implemented school-wide in one of the national pilot contexts. In 2010, and again in 2011, the principal from this school reported impressive increases in student test scores. This principal strongly supports the Science-Writing Approach and offers his teachers professional development to implement it. His account:

> We have the New England Common Assessment Program for several states. The scores were released from Spring 09 and we had 42% proficiency in science. That's about the state average as well. I noticed our inquiry was lacking in science. I did some research on questioning, and I presented it to the state. Then I was thinking about how to publish some student work from science and I talked with [a consortium science support person] and she recommended Betsy's book [*Writing in Science*]. She shared it with a couple of my teachers so I got it for all teachers. We had a book group from September through March [2010]. [*Writing in Science*] became our bible. In our 3rd kit last year, we were fully implementing [the Science-Writing Approach] with support from [the science consortium]. Then we were able to go to Seattle [to the Writing in Science Institute, described in the following section].

In 2010, his students' test scores skyrocketed:

> Our school went up 32% points in [science scores]. It got state attention. It brought focus to writing and science. And another school did well too, and it was doing writing in science too. Our two schools got a lot of attention. The Commissioner of Education came to see our inquiry science because the northern part of the state wants to go back to textbook science.

Again in 2011, after continuing the Science-Writing Approach, their science scores increased:

> We just received the 2011 scores for the state test. We increased 11 more percentage points [rounding] to 86% proficiency. We have the number one score of all… [of the state's] schools. Also, the four elementary schools in my district have an average of 81% proficiency, which is the number one score for districts at the elementary level [in the state].

In interviews with teachers in different geographic locations, two years after they completed the two-year pilot of the Science-Writing Approach, we asked if they had stayed with the approach and why. All six of the teachers had stayed with the approach, and two justified their persistence claiming increases in student test scores. One of these teachers says she is "sticking with" the approach because it appears to help raise achievement:

> My first year doing [Science-Writing Approach], … the kids were really low on our state data from our science assessments that we have to do every year. The next year, I had a really low group coming in for science and I was a little worried how they would do with science conclusions. After that second year of doing science writing, none of my kids were below or not meeting [expectations] on our state assessment. All of them were either meeting or exceeding [expectations] in science and that was a huge difference from before when I was not using Science Writing. I stuck with it because of that testing data. *4th grade teacher*

New science standards are currently in the pipeline. With its combination of inquiry science and science-based literacy development, the Science-Writing Approach appears well positioned to help teachers address multiple practices and cross cutting concepts in the new draft *Framework for K-12 Science Education*.

- **Potential for even greater student benefits**

A hallmark of the Science-Writing Approach is its structured process for prompting and scaffolding students' scientific thinking and expository writing. Mostly, independent reviewers and evaluators alike see the benefits of the scaffolding, which supports deliberate development of concepts and skills. However, across our studies outside reviewers temper their generally high level of enthusiasm for the potential of this approach by suggesting the benefits that more open-ended writing prompts could yield, extending the conceptual possibilities of district science units (Stokes, et al., 2002, 2005). One independent teacher reviewer, referring to Seattle's third grade unit on plant growth, says this:

> There also were some questions that to me seemed to beg for further investigation. Like what would happen if we planted the brassica plants outside… I didn't see a place in any of the notebooks where that was allowed for follow-up, that component wasn't present.

Other reviewers find that while many notebooks show strong evidence of authentic work and thinking in science, some also reveal a pattern of over-structured or perfunctory, formulaic student responses. Two reviewers say this:

> There was a confirmatory character to what the kids are after, instead of exploratory. There was less coming back to things to puzzle over. The student is just going along a conceptual story line—exploring is limited. There's very little "Why is it important to do this?"

> Some teachers provide a lot of structure in what the children record, while others seem to give the students more leeway to put their own thoughts down. [In three of six notebooks] I felt they were just filling in the blanks. Not much independent thought.

One reviewer contrasts the six notebooks that he read (two at each of three grade levels) with the notebooks of working scientists. He finds that the student notebooks seem "more like cleaned-up accounts of inquiry… that emphasize collection of data moving to clear explanation, without the 'struggle'" of actual inquiry.

Fundamentally, although the reviewers strongly value the use of notebooks to record scientific processes and data through writing, as well as to craft well-organized explanations of scientific information, they note that the approach did not promote students' writing-as-thinking. In other words, they want students to have more opportunity to write through the "struggle" that takes place *between* data collection and the well-crafted explanation.

In summary, the reviewers are convinced that the Science-Writing Approach enhances student learning opportunities in science beyond what is typically found in elementary science classrooms—and at the same time, they believe the approach should evolve to increase emphasis on and support for student-generated inquiry and more independent thinking and expression. What the reviewers observe in the notebooks persuaded them that science writing is the vehicle for offering students these kinds of learning experiences.

CLAIM 3: Putting the Approach into Practice Requires a Foundational Inquiry-based Science Curriculum and a Variety of Professional Development Supports

Evidence strongly points to the benefits of the Science-Writing Approach for student learning and to the desirability of spreading the approach more widely. Given the complexity and specificity of this approach, we wondered about the challenges of large-scale implementation. Two questions concerned us. First, to what extent can teachers who vary in their access to professional development support for this approach, in their access to high quality science programs in different district and state contexts, and in their understanding of and ability to teach hands-on science, adopt the approach? And second, would partial or low-fidelity implementation provide some benefits to students, and to what extent, if any, might partial implementation produce detrimental effects?

We explored these questions in two stages. First, in 2005, we studied implementation in Seattle among teachers who had had a "typical" amount of professional development in the Seattle model; then, between 2006 and 2011, we studied a national pilot of implementation in districts and states outside of Seattle. To provide context for these studies, it is important to understand what implementation supports Seattle teachers receive as part of the Science Writing Program:

The Seattle implementation strategy

Seattle Public Schools supports a K-5 science program that includes three hands-on, inquiry based units (or "kits") per grade level per year (totaling 18 units K-5), with professional development workshops that focus on the science content and instructional strategies for those units. The Science-Writing Program is built on this foundation and has three components of its own:

Professional development. Teachers begin with a three-hour workshop that introduces the approach as designed for grade-level clusters, K-2 or 3-5. Next, teachers can take a set of three 90-minute workshops (fall, winter, and spring) targeted to specific grade levels. Each workshop focuses on different aspects of the Science-Writing Approach (e.g., writing scientific observations, using strategies to organize thinking and writing, strategically using word banks to develop content understanding and terminology) within the context of science units for that grade level.

Supplemental science-writing curriculum. Teachers receive supplemental science-writing curriculum specific to each of the 18 hands-on science units used in grades K-5. Each science-writing supplement includes focus questions for investigations and writing, as well as thinking/writing frames and graphic organizers, and thinking/writing teaching strategies designed for the specific lessons in each unit. These curriculum supplements are introduced in conjunction with the professional development workshops.

Teacher leadership development. The Lead Science Writing Teachers (LSWTs) include three to fourteen teachers per grade level. They meet eight times per year to discuss and improve their instructional practices through assessing students' notebook entries (using protocols developed in accordance with the Science-Writing Approach) and planning instruction. They also assist in field-testing and revising curriculum strands and materials for science-writing workshops, and science-writing curriculum and supplemental guides. These teachers actively participate in the science-writing workshops before they are invited to become LSWTs. Many of them also go through an apprenticeship program in which they learn how to lead workshops in the teaching of the hands-on/inquiry science units.

Studies of implementation without full program support

Seattle

While the 2002 and 2003 Seattle studies focus on the approach as it is realized quite fully in the classrooms of Lead Science Writing Teachers, who received considerable ongoing support for implementation, the 2005 Seattle study explores the extent and nature of implementation in classrooms of teachers who are not LSWTs, but instead, have a "typical" amount of professional development in science writing in the Seattle context. For this study, we defined a "typical" amount of professional development as between 4.5 to 7.5 hours, that is, the introductory workshop and from one to three grade-level workshops over the course of one or two years.[19]

Panels of experienced LSWTs and independent experts in science education and writing analyzed student work in 150 science notebooks sampled from the eighteen teachers' classrooms. LSWTs assessed the extent to which class samples of notebooks reflected full program implementation, and the degree of individual student development in three areas: conceptual understanding, scientific thinking, and expository writing. A panel of twelve independent experts in science education and in writing assessed the extent to which the student work in notebooks reflected student learning experiences and goals that are important to the broader science education improvement community.

We found that of the 18 Seattle teachers in the sample, 8 were implementing the Science-Writing Approach at a quite strong level. In 2 of these 8, the level of implementation was comparable to that of a Lead Science Writing Teacher. Of the other 10 teachers, 7 were implementing the approach partially but inconsistently, and in 3 cases, there was little or no evidence of implementation, nor of any other consistent approach to science notebook use. Most reviewers took a "glass half full" stance, stating their confidence that teachers would be able to improve their use of the notebooks and achieve full implementation if they kept at it. However, some of the Lead Science Writing Teachers were concerned that in the future teachers would have to "un-teach" habits of notebook use developed in the classrooms where implementation of the Science-Writing Approach was most minimal.

The majority of LSWTs and all the outside experts who reviewed student notebooks concluded that even minimal implementation of the Science-Writing Approach is better for students than no use at all of the strategies. They judged that while full implementation is needed for full benefits to students, modest implementation has some benefits with few detriments. The LSWTs note that in notebooks from classrooms where implementation is evident but not truly full, student work tends to be overly mechanical. The outside experts similarly note that in some notebooks, students' writing is over-structured, leaving too little opportunity for independent thinking and the kind of grappling with meaning-making that scientists do through writing.

National pilot

Between 2006-2011 we studied teachers in five different locations outside Seattle (including 3 different states), exploring what promise the approach holds for teaching and learning in classrooms without the benefit of Seattle's well-specified professional development and leadership program. Teachers did not have access to any components of the Science-Writing Program; rather, they had access to the *Writing in Science* book as well as pilot protocols designed to support individual and group learning among teachers. Furthermore, districts varied in the extent to which

[19] See Stokes, et al., 2005 for further details on sample selection.

local leadership for science existed and whether a solid foundational science program was in place. Groups of teachers met in monthly study groups for two years often with no additional support. In just one state, teachers had access to a higher level of support from their principals, district, and lead teachers in an elementary science consortium. This provided a contrasting case to the more typical conditions of teachers working on their own.

We conducted an exploratory review of 69 student notebooks from classrooms of 23 pilot teachers in two states.[20] To capture the variation in notebooks, we developed two rating scales. The first describes the apparent *science foundation*, both the curriculum and the quality of teaching, which provides the context for implementing the science-writing strategies. A rating of 1 denotes evidence of a weak science curriculum (meaning no kit or other research-based science program) and weak implementation of it; 2 denotes a weak science curriculum and fair implementation; 3 denotes a sound curriculum (a research-based science unit, for example a FOSS or STC kit) and weak implementation of it; and a 4 denotes a strong science curriculum and strong implementation of it. The table below shows the ratings for science foundation assigned to the sample notebook sets.

Table 2. Ratings of science foundation
In pilot classrooms outside of Seattle

1	2	3	4
Weak curriculum, weak science teaching	Weak curriculum, fair science teaching	Strong curriculum, weak science teaching	Strong curriculum, strong science teaching
	1 set*: 2/3**	15 sets 1 set: 3/4	6 sets

** "set" is one teacher's sample of three notebooks*
***2/3 means a mix of teacher constructed and research-based kits*

The clustering of "3" scores indicates that the majority of the teachers had research-based kits (which was a pre-condition for participating in the pilot study); however, the student work in their science notebooks suggests that most teachers only partially taught the kit, or were weak in their implementation of it.

The second rating scale describes the *implementation of the science-writing strategies*. A rating of 1 denotes little or no evidence of the science and writing strategies or random implementation of them; 2 denotes evidence of the use of a few strategies; 3 denotes the use of multiple strategies, but inconsistently; and 4 is thorough and purposeful implementation of the strategies.

[20] Each teacher selected three notebooks, one each from a low, medium, and high-performing student.

Table 3. Ratings of science-writing implementation In pilot classrooms outside of Seattle

1	2	3	4
Little or no strategies	A few strategies	Multiple strategies, with inconsistency	Thorough implementation
8 sets*	9 sets	6 sets	0 sets

** "set" is one teacher's sample of three notebooks*

The ratings show that 15 of 23 pilot teachers were able to implement a few key strategies that got students started writing in science. Six sets of notebooks from Table 2 ratings of science foundation above show evidence of strong science curriculum and implementation of that curriculum, but Table 3 shows no evidence of full implementation of the Science-Writing Approach. The notebooks that showed a strong science foundation evidenced multiple strategies associated with this approach but used them inconsistently; or, if the notebooks had volumes of writing, it was documentation of science processes (e.g., steps in an experiment), with little or no evidence of conceptual development and meaning making which is the hallmark of the Science-Writing Approach.[21]

We were not able to conduct a formal study of student benefits in the classrooms of the national pilot teachers because of the limitations of the timeframe of the grant. Our exploratory analysis of student notebooks suggested that teachers had not had enough time with the approach or enough support for a study of this kind to hold promise.

Follow-up interviews in Fall 2011 with a sample of six teachers from four states found that the teachers still value the approach and are continuing to implement some science-writing strategies, even after three years. However, these teachers' tendency is to stay at a beginning to high-beginning level of implementation rather than continuing to move toward fuller implementation of science writing. We learned that for typical teachers, their commitment alone is not sufficient for ongoing improvement and fuller implementation of the approach.

One national pilot site differed from the rest in that the surrounding region had benefited in previous years from NSF funding for elementary science professional

[21] Caution should be taken in over generalizing these exploratory ratings because the teachers who shared their student notebooks had been implementing the program for only two years, and it typically takes three years or more for teachers to feel confident teaching science writing, even with the benefit of professional development. Additionally, the sample of teachers from whom student notebooks were drawn did not include the teacher leaders who more readily and fully implemented the approach because they were not participating in the study at that time. The analysis is useful, however, in building an understanding of what it takes to support implementation of the Science-Writing Approach at a level that yields close to full benefits to students.

development through the Systemic Change Initiatives. The districts we studied had been able to sustain support for their elementary science programs, including the development of teacher leaders for science. Here, teacher leaders achieved a level of understanding and comfort with the science writing strategies and purpose similar to that of accomplished Seattle teachers. These teacher leaders were further along the developmental continuum of implementation of science writing after only one year than most teachers in other sites after two or three years. They reported that they were designing their own focus questions and had grasped the importance of and were implementing modeling of writing for their students. The following carefully articulated approach to teaching writing shows this first grade teacher leader's depth of understanding after less than a year implementing the approach:

> The first time I introduce a type of notebooking entry, I always make sure that I do it on chart paper for them and I write their ideas for the shared writing piece. Sometimes I have them come up and write a word and we really take our time. I usually drag these lessons out a couple of days. The next day I go back and I want them to come up and highlight the important words that we were looking at when we were doing this, like underlying <u>same</u>, underlying <u>different</u>. How many things did you find that were the same? Tell me about the things that were different. Then the next day, we do the shared writing piece together, filling up the chart paper. 'I noticed that the vial of sand and the vial of clay are similar because they are both…' and they would tell me. It is time-consuming, but it was worth taking the time. The next day I did just the scaffolding, 'the blank and the blank are similar because' and then 'the blank and blank are different because' and then I… give them the word 'whereas' if they need it and then they were able to write in their notebooks.

In summary, the national exploratory study added considerably to what we had begun to learn in Seattle about the "implementability" of the Science-Writing Approach without a program of professional development. We found that the majority of teachers in the national pilot were able to begin to take initial steps toward using the approach, but in most cases, their implementation remained partial after two years. Teachers tended to pick a handful of the more simple-to-use strategies and, when they got substantial payoff from them, to stay with them. These early-adoption strategies included using the phrase *I think… because*, having students create diagrams and scientific drawings with labels, and developing word banks.

In contrast, we observed very few instances where teachers used strategies at the more difficult-to-implement end of the continuum, such as modeling writing; writing conclusions that include data analysis and sense-making by synthesizing learning from several lessons related to a scientific concept; and designing and using focus questions. Very few teachers were able in two years to understand and implement the teaching and learning sequence as presented in the publications (e.g., science investigation, shared reflection, shared-writing mini-lesson). We also learned that, where there is an absence of systematic professional development, the nature and extent of partial implementation of the Science-Writing Approach is, predictably, teacher dependent. Instead of seeing strong sets of notebooks from teams or schools, the common thread among notebook sets where there is fuller implementation is the quality of the teacher's basic science teaching. In the one district where there is a strong and well-supported science program and sustained investment in teacher leadership, we saw that highly competent science teachers could skillfully implement the approach.

Factors that support fuller implementation

The full complement of support for teachers to learn to do science writing in Seattle includes a menu of introductory and grade-level specific workshops, supplemental science-writing curriculum for each of Seattle's 18 elementary science units, and a Lead Science Writing Teacher leadership development strand. With that level of support, teachers who are committed to the approach and are working in a school where time is given to science can achieve quite full implementation in two or three years.

Teachers in other districts do not have this level and variety of supports. Even so, teachers outside of Seattle in a wide range of settings with varying capacities to teach hands-on science were able to get started using the approach. These teachers reported that the supports they had available to them were helpful—reading *Writing in Science* along with working in teacher study groups of mixed grade levels where they used preliminary materials from *Writing in Science in Action* that were aimed at building their understanding of the approach by, for instance, taking them step-by-step through *Writing in Science*, analyzing models of teaching on a DVD, and using guidelines and criteria for looking at student notebooks. **We find that this level of support is essential for teachers to include science writing in their teaching at all; however, it is not sufficient support for them to reach fuller levels of implementation.**

The work of teacher leaders in the one exceptional national context contributed to our understanding of what is needed to move to fuller implementation in the absence of Seattle's comprehensive support. The fuller implementers in this context were teacher leaders: master teachers who provide professional development to other teachers for science teaching in districts that have well-developed and sustained kit-based, hands-on science programs. The teacher leaders had a strong foundational science program, meaning a research-based science curriculum and units, which they taught with confidence and understanding. A regional consortium provides elementary teachers with unit and grade-level-specific professional development in science (and they have now begun to include science writing in their introductory kit trainings). Six out of eight superintendents in this context purchased the book, *Writing in Science*, for all teachers in their districts.[22] Importantly, the teacher leaders had additional local support from their principals for implementing science writing, which pilot teachers in other areas did not have.

[22] In this context teachers participated from a number of different small districts that belong to a consortium, which continues to work together to provide professional development and other support for teachers in kit-based hands-on science. It started as a NSF Systemic Change Initiative.

These principals were highly involved in and supportive of the study groups and implementation of the Science-Writing Approach. In fact, their entire schools were actively participating in the study groups and moving toward school-wide implementation of the approach.

The teachers reported how much they valued these supports:

> I feel like I am really lucky in that we are getting a lot of support. My principal was a master teacher herself who really enjoyed teaching science, and she gets it in a way that many administrators really don't get. *4th grade teacher*

> My principal bought us all of the science and writing books, and he mapped out the chapters throughout the year and so there were certain science and writing chapters that we were responsible for trying a few of the things, reading them, and trying a few of the things with the class and then reporting back during our faculty meeting. *2nd grade teacher*

Even in Seattle, it is rare that teachers have principal support for school-wide implementation. Seattle teachers report that that level of support is desirable, saying they would be encouraged to devote more time to science and the full use of science writing if others in their school were also teaching science this way and talking about it together (Stokes, at al., 2005). In schools that do not place high priority on science or writing, teachers often feel they are stealing time from other subjects (math and reading first, other types of writing, sometimes social studies) when they teach science, and especially when they fully implement the program's approach to science notebooks into their teaching. Teachers with still-emergent confidence in science, in Seattle and nationally, are less likely to persist toward full implementation of the Science-Writing Approach in the face of time pressure caused by competing workplace priorities.

Most teachers in the study acknowledge that they would not be doing any writing in science at all if it were not for the Science-Writing Approach. The availability of the approach in the two publications—*Writing in Science* and *Writing in Science in Action*—provides a vision and strategies for teachers with personal commitment to teaching science and science writing (nearly always in the face of competing priorities in their schools) to begin implementation. To move toward full implementation, teachers need a solid science foundation and understanding of the key science concepts in a unit combined with substantial knowledge of expository writing and the Science-Writing Approach. Teachers become more able to choose the appropriate science-writing strategy to support student scientific thinking in lessons and to integrate it fully into science units. Teacher commitment and the availability of the *Writing in Science* books are just the starting point for the majority of teachers who are not already science leaders. Actively supportive administrators who promote implementation of science writing school-wide in combination with district level professional development programs in hands-on science and teacher leadership development in elementary science contribute to fuller implementation.

CLAIM 4: There is a Need for, a Model for, and Leadership Capacity for Launching a National Professional Development Institute for Science Writing

Offering a science-writing institute appears to be an essential building block in the scale-up process if the goal is to build the capacity of our nation's teachers to more effectively teach science by integrating science writing. Considering the significant ways in which the approach benefits students, including ELLs and other special needs students, and the challenges of putting it into practice in ways that optimize these benefits, a science-writing professional development effort that reaches beyond Seattle is desirable and warranted.

In February 2011, Betsy Rupp Fulwiler, a core group of LSWTs in Seattle, and the administrative staff rose to the call for professional development in science writing by piloting a national Writing in Science Institute. The pilot Institute for Writing in Science holds substantial promise as a model for a national effort to support teachers who want to learn to integrate science and writing similar to what the Exploratorium's Institute for Inquiry[23] does for teachers who want to learn best practices around inquiry. A select number of well-chosen teachers attended the pilot institute by invitation. The participants included 15 teachers, 3 principals, and 2 science coaches from three states including Washington. Based on their eagerness to attend and their reflections on the value of their experience, an ongoing institute modeled on the pilot would have a national appeal.

The Writing in Science Institute serves teachers at all levels of implementation and augments teachers' learning from the Writing in Science books

The content of the Writing in Science Institute focused on the interaction between hands-on inquiry science and expository writing.[24] A key aspect of the successful design of the institute was that it worked to move teachers at different stages of implementation from beginning to high end further along in their grasp of the approach. Well-designed activities offered participants opportunities to learn about the approach, to observe it in action in classrooms, to work with Seattle's LSWTs considering student work from the observed classes as formative assessment, to think about student assessment, to do their own expository writing as part of their own hands-on inquiry, and to write focus questions with coaching from Seattle's LSWTs. For teachers in the more initial stages of implementation of science writing, it offered enough experience with science notebooks and expository writing to enable them to understand how this Science-Writing Approach is distinct from many district-prescribed writing curricula, understanding what it means that the approach emphasizes scientific thinking and does not take a lock-step approach to teaching formulaic writing. For the fuller implementers, it illuminated the more challenging aspects of the Science-Writing Approach such as the teaching sequence, how students' oral reflection on their inquiry experience is an integral part of the

[23] See http://www.exploratorium.edu/ifi/.
[24] The pilot Writing in Science Institute did not seek to build participants' science content knowledge

writing process, and the interface between the science conceptual development and the writing. Two representative comments from fuller implementers:

> I think the most amazing transformation that I experienced as a result of [the institute] is seeing the whole process in the classroom. I got to go into the classrooms and watch them go through the whole process with their kids and be able to observe how they interact with the kids and going through all of the components of the learning cycle that they used, including the writing. That was amazing for me, because I have never really seen it in totality. I have only seen parts of it. I have only seen some of the video clips… the ones that go along with their book which are just parts of the whole big picture… Ever since I have come back from that training, I just have been able to do the whole thing the way it is supposed to be… I completely and finally got it. I saw what it looks like, I see what it sounds like and I can see, based on not only just teacher behavior, but also kid behavior. Then I was able to come back and look at myself and say okay, what am I doing and what do I need to do better and how would I need to change… I am just going so much deeper, and it is going so much better because I felt like I finally had really almost internalized everything. It wasn't just like me trying to follow a manual, it was me really understanding, and that was really powerful. *2nd grade teacher, high implementer*

> I think that being a part of the institute and realizing the gaps that we had in what we were doing, the making meaning questions and the shared writing were the two main things that we took away, saying, "This is what we need to do." The student response, we instituted that, and I couldn't believe their level of science thinking just jumped up like 10 notches from having that discussion and that making meaning and then the shared writing. We actually recently took our science state testing and I could not believe the level of writing that they were doing. They have to write inside boxes and they were running out of room because they had so much to say. It was all good science content, it wasn't just that they were filling up the boxes, and so, I have never seen any group of students work so hard and I attribute it to the work that they have done with the writing and the discussion." *4th grade teacher, intermediate to full implementer*

All participants also valued the opportunities the institute offered to rethink assessment and learn new ways of using and responding to student work. Teachers referred to a shift in their focus from judging grammatical and mechanical correctness in student writing to focus on clarity and accuracy of expression of science concepts.

The Institute built Seattle's leadership capacity to serve a national audience

The pilot Writing in Science Institute provided a test ground for Seattle's capacity to offer a national Writing in Science Institute. The institute offered five of Seattle's most experienced LSWTs their first formal opportunity to provide professional development on the Science-Writing Approach, and to serve a national audience. These LSWTs have been helping to develop the Science Writing Approach for nearly ten years, and have worked with the Seattle elementary science program as coaches and teachers, offering initial use workshops for science units and facilitating LSWT meetings. Supporting other teachers' learning of the approach was a fresh and challenging experience for the LSWTs, which they rose to and learned from. Two of them commented:

> I really do know this stuff pretty well. The content certainly wasn't new, just the actual format of presenting it. And certainly hosting people from other districts, that was the first time that I have ever done that. Science writing, I have done that for years. I have been facilitating that [LSWT] group for a few years, observing in other teacher's classrooms and I have done that more just as a coach… [Facilitating the institute] really gave me a different perspective on the whole program and the ability to really disseminate, and [to realize that] actually more people could get more out of this. *LSWT*

> To see all of the work that we have been putting in over the past ten years to the science writing program just come to life made me re-energized about the whole program and made me want to have an institute here. It seems like other districts really want this kind of professional development. *LSWT*

The experience of contributing to the institute program and design served as an important leadership capacity-building vehicle for the LSWTs. They have growing confidence and desire to extend their leadership growth and opportunities both within and outside of Seattle.

At least two groups of institute participants were eager to have ongoing support and requested follow-up site visits. While the leadership team was able to meet one request, the team does not have the capacity to offer this type of on-site support. There are also districts across Washington State that are interested in the approach and are seeking support in implementing it. To support the many educators who have expressed interest, establishing a national Writing in Science Institute—one that is ongoing and that continually supports implementation and also builds greater leadership capacity-is a desirable strategy to begin to provide the level of support teachers need to fully implement the Science-Writing Approach.

III. The Science-Writing Approach as an Investment in Educational Improvement

The gap between where our students are in their science learning and where we want them to be, combined with the development of new standards in science, create a climate of urgency for scaling up effective programs such as the Science-Writing Approach. Students need to learn significant and worthwhile content through investigations, recording, analyzing, and interpreting data, constructing their own explanations, using evidence to support their arguments and claims, and identifying, evaluating, and communicating their learning. The evidence collected over ten years of evaluation shows that the Science-Writing Approach offers students, including English language learners and special needs students, opportunities to develop and use these abilities as an integral part of the process of learning science and scientific thinking. Science writing integrated into an inquiry-based science program supports the development of evidence-based reasoning, in science, and in other subjects too. All the nation's students deserve to have the full benefits of an approach with such promise for improving student learning.

Evidence suggests:

- The approach offers students opportunities to learn science and expository writing in ways that are more sophisticated in quality, and reflective of greater rigor and a higher level of learning of both science and writing, than is typical in elementary science programs. When fully implemented, the Science-Writing Approach creates interplay between students' conceptual development and sense making in science and their development as expository writers. Science provides the subject matter for learning expository writing and the writing furthers students' understanding of science context.

- The approach can improve student achievement in science and writing and contributes to more equitable achievement for learners with special needs, especially ELL students and others struggling with literacy in English.

- The available publications, *Writing in Science* and *Writing in Science in Action*, make the approach accessible to any interested educator. In addition to offering a nuanced rendering of the Science-Writing Approach, the supplemental materials in *Writing in Science in Action* are of high quality and include cutting-edge models of teaching in a DVD, online support for teacher study groups, and written accounts by teachers at different grade levels who have experience with the approach. Successful implementers begin by reading *Writing in Science* and working in teacher study groups using *Writing in Science in Action*.

- The Science-Writing Program is implementable in contexts where science is a priority, where teachers have a strong foundational science curriculum on which to build, and professional development support that enables them to reach the fuller level of implementation that generates benefits to student. Teacher commitment to teaching science and science writing is necessary but not sufficient to reach the fuller levels of implementation. In an overcrowded curriculum, teachers need actively supportive school-level administrators who promote implementation of science writing school-wide in combination with district level professional development programs in hands-on science and teacher leadership development in elementary science.

- Teachers who implement a combination of research-based hands-on science and science writing together have greater potential to teach the multiple practices and cross cutting concepts in the new *NRC Framework for K-12 Science Education*.

- Scaling up the Science-Writing Approach will require a national strategy—one that includes support for a national institute as well as a network infrastructure supporting national and local leadership development. Seattle's successful pilot Writing in Science Institute, in combination with an emergent statewide network of teachers and districts in Washington State, are key building blocks for this vision.

Glossary of Acronyms

CRESST	Center for Research on Evaluation, Standards, and Student Testing (UCLA)
NAEP	National Assessment of Educational Progress
NCES	National Center for Education Statistics
NRC	National Research Council
LSWT	Lead Science Writing Teachers in Seattle
PISA	Programme for International Student Assessment
STEM	Science, Technology, Engineering, and Mathematics
TIMSS	Trends in International Mathematics and Science Study
WASL	Washington Assessment of Student Learning.

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