Why Involve Families in a Science Education Program?

Research strongly indicates that families’ active participation in their children’s schooling improves student achievement. Thus, family involvement in children’s learning is a crucial component of any systemic and sustainable change in education. This rationale is based on the benefits of parent participation in a child’s education, the conviction that informed parents are more likely to become advocates for high-quality science education, and the critical role involved parents can play in advancing science education reform as their children move from elementary school into secondary school.

Education reform is a complex, involved, and lengthy process. Research and experience in science education reform has shown there are at least five key elements in a successful science education program:1

1. Adopting and implementing inquiry-based science curriculum and materials.
2. Including professional development for teachers that provides both rich content knowledge and inquiry-based teaching and learning strategies.
3. Supplying materials and apparatus to classrooms through a centralized materials support system.
4. Implementing assessment methods consistent with the goals of an inquiry-based science program.
5. Building strategies for administrative support and community participation to sustain commitment to science education reform.

A Family Science program that is strategic, purposeful, and reflective can be a catalyst to supporting science education reform.

Specifically, the Family Science project at the Institute for Systems Biology was created with the mission to empower families to learn science together and to build community support for inquiry-based science education. The Family Science project was designed to support the fifth key element of reform: community participation. The project goals were to:

- Engage communities that are traditionally underrepresented in science careers.
- Build networks of support and leadership for quality science education and literacy within Seattle schools and local communities.
- Engage families in student learning.
- Reduce barriers for students and families to fully participate in quality formal and informal science education.

These efforts reflect the nation's vision for developing citizens ready for the challenges of the 21st century.

“Family Science taught us to let the teaching come from the family through parents, grandparents, and older siblings working with students. Family Science helped demonstrate that learning happens at home and in the community.”

–Principal of Elementary School
Almost 50 years ago, the Soviet Union shocked Americans by launching Sputnik, the first Earth orbit satellite. That event called for increased attention to our nation’s Kindergarten through 12th grade science education. The “best and brightest” students were encouraged to take science electives and consider careers in science or engineering. For these select students, new science textbooks and lab equipment were supplied to science departments. This group of students benefited from an increased emphasis on science education.

But women, minorities, and average students were not exposed to this rigorous science curriculum, nor given the opportunity to explore science concepts as they related to the world they lived in. As a result, this type of science education actually widened the achievement gap among these groups. Even with the emphasis on increasing our prowess in science and technology, new science courses were not thought of as core subjects.

Today, contemporary science education supports educating all students, with a particular emphasis on closing the achievement gap. Curriculum and teaching approaches have changed and these changes are supported by educational research and student achievement data. By attending to the learning of all students, not only is our education system filling the pipelines to science and engineering colleges and our national workforce, but it supports the development of a literate citizenry with an ability to think critically and continually learn. Simply put, contemporary science education is preparing citizens and the workforce for the future.

To address these issues, scientists, educators, and educational researchers convened over the past two decades to study how people learn science. More specifically, the term standards has been provided for documents that outline a sequence of what students should know and be able to do. These documents summarize research on what children are developmentally ready to learn and in what order concepts need to be introduced and taught. To accompany the “what” and “when” of teaching science concepts, there have been several studies on effective “best practices” for teaching science. We now know that passive reading or listening to lectures is not enough to form a lasting understanding of scientific principles or develop scientific skills. Rather, learning must be student-centered. This entails actively constructing new knowledge by connecting old ideas and beliefs to new information gained through personal investigations and discovery provided through classroom experiences.

This contemporary way of teaching and learning has been described as inquiry-based science and is the central component of this guide. Research demonstrates that by infusing science programs with inquiry, significant improvements in scientific achievement occurs for all students, including those from underserved populations, and contributes to students' overall success in school.

Hence, understanding inquiry-based science in the context of classroom learning is fundamental for developing a Family Science program.
Defining Inquiry-based Science

Inquiry is a search, an active process of understanding not simply the transfer of information or knowledge. Teachers, science educators, and curriculum developers have designed models for incorporating the process of inquiry into classroom practice. Inquiry-based science can be described in terms of what students do in the classroom, what teachers do to support the inquiry process, and how instructional materials support teaching and learning.

What Students Do

In the inquiry-based science classroom, students are not passive; rather, students engage with science content in a manner that parallels the process used by scientists. Students explore and discover science through a process of inquiry by:

- **Focusing** on the content at hand through observations and questions
- **Exploring** these ideas with hands-on experiences
- **Reflecting** on what they have observed or measured to make meaning from their experiences
- **Applying** and extending their findings to new questions or problems.

What Teachers Do

Teachers support student inquiry-based activities by facilitating students' scientific understanding through:

- Assessing student prior knowledge
- Asking guiding questions, without providing answers
- Arranging the classroom to promote collaboration and communication skills
- Providing focused opportunities for open-ended investigations
- Modeling analysis techniques
- Fostering reflection and critical thinking skills
- Providing real-world connections and integration with other subjects.

How New Science Curriculum Supports Teaching and Learning

Newly developed science curriculum supports the standards and best teaching practices for inquiry-based science learning. These materials highlight how students can build deep conceptual understanding of science concepts starting from their own curiosity, observations, and questions. By capitalizing on students’ natural inquiry abilities, many topics can be approached in the early grades and built upon in later years.

This way of learning makes possible deeper understanding and better retention of science concepts. In addition, the new science curriculum simultaneously builds both students’ content knowledge and process skills, paralleling the experiences of working scientists. Moreover, and perhaps far more importantly, the new science curriculum promotes students' development of problem-solving, communication, and collaboration skills applicable to everyday life situations.

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What an Inquiry-based Classroom Looks Like

When observing a traditional versus inquiry-based science classroom the subtle shift in teaching and learning may not seem immediately apparent. Students in both classrooms are found reading, making observations, asking questions, conducting experiments, and making interpretations. Both include direct instruction from the teacher. A major difference, however, is that in an inquiry-based classroom teachers use instructional materials and teaching strategies that harness students’ innate curiosity for knowing “how we came to know” things rather than confirming “what we know.”

These next two examples illustrate the differences between “what we know” and “how do we know.” These classroom vignettes demonstrate how inquiry-based learning experiences extend beyond the learning of facts and hands-on activities. It shows how, through teacher-to-student and student-to-student discourse, deeper, more fundamental learning occurs using inquiry-based instruction.

Example of a traditional science lesson:

As the 7th-grade students filed to their desks, placed in rows in the classroom, Mr. Jones asked the students to get out their textbooks, paper and calculators. As homework the previous night, the students were given pages 81-84 to read in their textbooks, which defined the term density. Mr. Jones began the class by reviewing this reading, “Today, we will study one property of all matter – density. Who can give me a definition of density?” Sam raised his hand and replied, “Density is the mass divided by the volume.” Mr. Jones continued by writing the mathematical equation of density on the board and explaining the common units of density measurement: grams per cubic centimeter or grams per milliliter.

Density = \frac{mass}{volume} = \frac{grams}{cubic centimeters} = \frac{grams}{milliliters}

Next, Mr. Jones provided students with sample calculations and posed the task: “Calculate the density in grams per milliliter of aluminum if a 50cc block has a mass of 135g.” Students copied the information from the board and performed the calculation. After confirming the correct answer, 2.7g/cc, Mr. Jones proceeded to introduce the lab activity for studying density.

Mr. Jones passed out a laboratory handout that included the definition of density, a lab question, list of materials, and specific procedural steps. The students were asked to move to lab stations and complete the lab activity over the next two class periods. At each lab station, students were supplied with several uniform chunks of metal, wood, plastic, cork, and a sheet of foil. Students were asked to determine the mass and volume of each sample using a gram scale, ruler, and graduated cylinder of water as demonstrated by Mr. Jones. An additional page of sample calculation problems was to be completed as homework. The calculations and a written conclusion for the lab activity were to be turned in at the end of the lab period the next day.

The following day, Mr. Jones monitored the behavior of students in their lab groups. He clarified questions about the procedure and handling of equipment as needed. At the end of the lab, students exchanged their papers and Mr. Jones provided the answer key on the overhead. The corrected papers were collected and entered into the grade book.

Mr. Jones reminded the students that a quiz on this material would occur in two days and would include calculations for density and a practical exam on using a gram scale.
In a classroom where students are looking for a "correct" answer, the instruction follows more traditional methods, such as giving students scientific facts and definitions in lecture format and repeating laboratory procedures that lead to a specific, known result. Scientific concepts are often presented quickly and in only one setting.

In the previous example, Mr. Jones directed the class through all the steps to confirm what already was known. Research shows that many students have difficulties applying and extending the concepts learned from these types of experiences to new situations. Research also indicates that students approached in this manner quickly become disinterested and have difficulty seeing the relevance for how this information will be useful in their own lives, beyond remembering the facts for a test. Traditional methods may be hands-on but not necessarily minds-on.

Example of an inquiry-based science lesson:

Ms. Rodriguez greeted her students and invited them to sit in their cooperative groups at the lab stations in the classroom. "Before we begin our investigation today, I would like you to watch a brief demonstration," she said. Next, she asked the students to predict what would happen when she placed an ice cube in two separate glasses of clear liquid. Meredith guessed that the ice cube would float in the "water," since that is what happened at home. Siry agreed with Meredith, recalling that icebergs float. Most students nodded in agreement. Ms. Rodriguez then placed the first ice cube in the first beaker and it floated, but in the second beaker a second ice cube sank to the bottom. The students were visibly shocked. Jose asked, "What’s your trick?” “Good question. Are there more questions you would like to ask about this system?” Ms. Rodriguez replied. Ms. Rodriguez and her students discussed the students’ original assumption that the liquids in the beakers were water. Ms. Rodriguez asked, "Based on what you just experienced, how might you alter your assumptions?” Ms. Rodriguez and her students discussed the properties of the two liquids—both clear and non-viscous. Students then asked their teacher to place the first ice cube in the second beaker of liquid to see if the same result would occur. The first ice cube sank just as the second cube had. This prompted other students to ask further questions and examine the liquids and ice cubes more closely. Through their observations, the students inferred the cubes appeared to be normal ice cubes, but the first beaker contained water and the second beaker contained rubbing alcohol, as noted by the smell.

Ms. Rodriguez questioned the students about what they knew about floating and sinking from their own experiences and made a list of their responses on the board. Next, she prompted the students to extend the idea of floating and sinking with the variety of materials found at their lab stations: plastic dishpans, water, metal containers, nuts and bolts, blocks of wood, bar of soap, Styrofoam, rubber bands, aluminum foil, shells, plastic lids, cork, a gram scale, and a graduated cylinder (measuring cup.) After their initial explorations, the class generated a list of floaters and sinkers. Ms. Rodriguez asked, “Which property of these materials might contribute to whether something floats or sinks?” Many thoughts were shared, including how much something "weighs," since several students had weighed the objects to make predictions about floating and sinking. At the end of the period, Ms. Rodriguez asked the students to create a concept map (bubble-arrow diagram) to explain their current ideas about floaters and sinkers as homework.

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As shown in the inquiry-based science lesson, students are motivated to learn when given the opportunity to pose their own questions and examine how the natural world functions. Teachers in inquiry-based classrooms empower students by providing a variety of opportunities and methods for students to observe, question, and investigate the world around them. As students build meaning from these experiences, additional opportunities to extend and apply the new information helps to solidify the knowledge and skills gained.

Studies show that learning science in this manner reflects how children naturally learn through experimentation, which facilitates connections between new information and former experiences or ideas. As a result, students retain more information and have a deeper understanding of science concepts.

Example of an inquiry-based science lesson continued from page 12

The next day, Ms. Rodriguez had the students complete a lab where they compared blocks of wood, metal, plastic, and cork placed in various liquids (water, oil, and alcohol) for floating and sinking. Ms. Rodriguez instructed the students about measuring the volume of an irregular ball of aluminum using the graduated cylinder and displacement of water and reviewed the use of a gram scale. After forming a common lab question, the students used the gram scale to measure the number of grams of each item and used a ruler or a graduated cylinder for determining the volume of each item. All this information was compiled with the original floater and sinker list and discussed as a class. Along the way, the students asked about the weight of objects and their ability to float. Ms. Rodriguez went from group to group to discuss this question. Students were able to state their results from the many different objects by developing the statement, "For every one unit of volume (cubic centimeters or milliliters), this object has a mass of X grams. This compares to water, which for every one milliliter always has a mass of 1 gram." Following this analysis of their experimental results, Ms. Rodriguez led a whole class discussion on weight versus mass. She was able to introduce the term "density" to be used for the concept of how much mass an object has for every one unit of volume and used this term to analyze the class data on floaters and sinkers.

Next, Ms. Rodriguez applied the concept of density to principles of engineering and the arts. The students designed ways to solve the challenge of how to make "floaters sink" by using sponges and lemons with and without their skins. Students then applied their findings to the next challenge—how to make an object float and sink at will—principles used in submarine design. Also, returning to Siry's original prediction, the class proved how icebergs float and what makes them dangerous to ships by measuring how much of a large chunk of ice is actually submerged under the surface of the water (i.e., about 9/10ths).

Ending the unit, Ms. Rodriguez demonstrated how to marble paper using the different densities of ink and water (i.e., the ink floats on the water in swirling patterns that can be transferred to paper). Students were fascinated with applying science principles in artistic ways. Students created their own marbled paper and constructed a final concept map of their understanding of density on the paper for their science notebooks.

The combination of all these lessons guided students through different activities that helped them develop an understanding of density and apply and extend the concept to new situations.

“Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.”

—Atlas of Scientific Literacy, pg. 15