HOW DOES LEADERSHIP MATTER? DEVELOPING AND TEACHING A DEFINITION OF HANDS-ON SCIENCE, A PREREQUISITE FOR EFFECTIVE INQUIRY TEACHING

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Abstract

This descriptive case study describes leadership skills and planning for setting clear directions by program leaders for a statewide professional development initiative to extend improvement in science teaching and learning. For science teachers and leaders in Virginia, a critical part of setting clear goals that everyone can understand is defining key science terms. One of the four key terms, "hands-on science," is defined here. Materials to develop teachers' understanding of the term for effective implementation of classroom inquiry activities are shared, along with a rubric for evaluation by and for teachers. Understanding of the term "hands-on science" is necessary before inquiry-based science teaching can be fully implemented. Authentic science materials, when safe, are necessary for doing authentic, inquiry-based science teaching in a way similar to how a scientist investigates science.

Leadership

Science education reform in the United States is dynamic and messy, as educators grapple with emerging challenges and demands. Leadership matters at all levels whether local, state, or national. Leaders in science education reform provide clear directions, are data driven, and influence policy and effective practice in science education. Their contributions are crucial to initiatives aimed at improving student learning and future workforce development [1].

Effective education leadership makes a difference in improving teacher and student learning. What is less clear is how leadership matters, what the essential ingredients of successful leadership are, and how to promote the learning of all students. Greater attention and investment in effective leadership is a pathway sought by many for large-scale education improvement. How do high-quality leaders achieve this impact? According to research, they use the following methods:

- Set directions – chart a clear course that everyone understands;
- Establish high expectations – use data to track progress and performance; and,
- Develop people – provide teachers and others with the necessary support and training to succeed [2].

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Leaders are able to influence teaching and learning through the contributions they make to positive feelings of efficacy. According to Bandura, one's belief in one's self and others determines the likelihood of setting a direction and achieving a goal. Self-efficacy is belief in one's own ability, whereas collective efficacy is belief in one's colleagues to perform a task or achieve a goal. Strong efficacy beliefs are key to leaders' ability to get things done [3]. They affect the choices leaders make and they affect coping efforts [4, 5]. The stronger the feeling of collective and self-efficacy is, the greater the persistence for a goal. The sense of collective efficacy for leaders at all levels, whether teachers, principals, science coordinators, or superintendents, is central to undertaking and persisting in school improvement for teaching and learning [6].

The report, *The Three Essentials: Improving Schools Requires District Vision, District and State Support, and Principal Leadership*, identified three critical aspects of leadership for school improvement based on a study by the Southern Regional Education Board of seven very different school districts [7]. They found that states and school districts must develop and communicate a clear coherent vision and a collaborative framework of support in order for school improvement to become a reality. In addition, they found that the most significant change was the mindset of district staff which includes holding themselves responsible for results.

If teachers and leaders are going to hold themselves responsible for results, they need to develop an understanding of what the results will look like, thus the necessity of defining relevant terms. According to the National Assessment for Educational Progress report released in June 2012, students doing hands-on projects in class score higher more frequently on student assessment tests, with students doing hands-on science almost every day scoring the highest [8]. Thus, if we want our students to score well on achievement tests, there is a need to understand the term "hands-on."

Two publications from the National Science Teachers Association (NSTA), *Position Statement: Leadership in Science Education* and *Position Statement: National Science Education Standards*, support the importance of leadership with a clear coherent vision of effective science teaching and learning and a collaborative plan for reform [9, 10]. The *NSTA Position Statements* also focus on the following: the importance of sustained professional development for teachers and leaders; the alignment of curriculum, instruction, and assessment; and, data-driven decision making. Effective professional development expands knowledge of content and pedagogical content, challenges the beliefs of teachers and leaders, and is transformative over time [11]. For sustained professional development impact, Horizon Research found in their study, *Lessons from a Decade of Mathematics and Science Reform: A Capstone Report for the Local Systemic Change through Teacher Enhancement Initiative*, that long-term sustained effort and support by district and local leaders is essential when implementing new instructional strategies and materials [12].

VISTA Program Description

The Virginia Initiative for Science Teaching and Achievement (VISTA) is a partnership among sixty-five school districts, six universities, and the Virginia Department of Education to build an infrastructure to provide sustained, intensive science teacher professional development to increase student achievement. The goal of VISTA is to improve science teaching and student learning, especially in high-need (high-poverty, high-minority) schools, as well as for limited English proficient students, rural students, and students with disabilities.

Through a validation study of previous targeted efforts, the programs are being extended across multiple school divisions. The initiative is funded by the United States Department of Education through the Investing in Innovation (i3) program, part of the American Recovery and Reinvestment Act. In conjunction with validating prior program research efforts, the grant-funded project has been designed to build leadership and shape policy, and practice through four intensive professional development programs: 1) upper elementary teachers (grades 4-6) receive professional development for one year in problem-based learning (PBL) science instruction, working in teams as they plan and teach PBL lessons; 2) first- or second-year secondary science teachers (grades 6-12) are provided just-in-time coaching and "big picture," research-based science teaching coursework for two years; 3) school district science coordinators focus on strategic planning for effective science teaching, data-driven decision making, and leadership; and, 4) university science education faculty members investigate new science teaching, and learning research and reform practices.

Research Questions

All four professional development programs require a common vocabulary. This study investigated the following questions: 1) What key words need to be defined? 2) What are the definitions of these words? 3) What learning materials help participants grapple with the meaning of these words? 4) What rubrics are helpful for assessment of implementation? This article focuses on "hands-on science," the first of the four terms introduced.

Methods

This descriptive case study describes how defining a critical term, "hands-on science," aided in developing a clear, common understanding by all constituencies across the Commonwealth of Virginia. The overall purpose of defining key science teaching pedagogy is to support the statewide infrastructure necessary to bring improvement to classroom instruction and student achievement.

Methods—Participants

This study chronicles the experiences of multiple participants at three stages of designing and testing definitions. Participants included the principal investigator (Caucasian, female), nine VISTA staff members from three universities (8 Caucasian, 1 African-American; 8 female, 1 male), thirteen school division science coordinators (8 Caucasian, 2 African-American, 1 Asian, 2 unknown; 10 female, 3 male), and eight science education university faculty (6 Caucasian, 2 African-American; 4 female, 4 male) from seven other universities for a total of ten universities. This article is based on the perspectives of the program implementers regarding challenges they encountered for the overall program as it was being created and implemented at the three program delivery sites for validation purposes.

Methods—Research Design

From the pilot studies, the researchers knew that common science pedagogical terms such as "hands-on" were used in different ways. Therefore, they were aware that definitions needed to be established for the program to successfully expand throughout Virginia. The researchers collected qualitative data concurrently from key program implementers throughout the Commonwealth as the program was initially being created and implemented.

Data collection consisted of participants' responses to surveys, observations, interviews, focus/working groups, and reflections. The surveys contained open-ended items and were administered pre-/post-professional development. The surveys were designed to elicit participants' perceptions of the effectiveness of the professional development and key objectives of the professional development regarding four pedagogical terms: hands-on science, inquiry, problem-based learning (PBL), and nature of science (NOS) instruction. Validity for the definitions and training materials developed was supported by review by a panel of experts with backgrounds in science education and research evaluation. The panel's revisions were incorporated into the final version of the instrument, a process which resulted in consensus on the face and content validity of the instruments.

Methods—Data Analysis

Qualitative data were analyzed using the constant comparative process of grounded theory [13, 14]. Grounded theory drove the determination of themes/categories. A comparison of themes occurred, which allowed preliminary answers to the study questions [15]. Analyses were reviewed by the research team in order to reach consensus.

Results—Four Science Teaching Definitions

An emergent theme was the discovery that teachers had multiple meanings for the same pedagogical phrase. In order to clarify the goals of VISTA and establish a common language and unity across the Commonwealth, four key phrases were identified and defined: hands-on science, inquiry-based teaching, problem-based learning (PBL), and nature of science (NOS). Only "hands-on science" will be defined in this article, including the process used to develop the definitions, the materials used with the teachers to establish common understanding, and the assessment materials to gauge progress.

Results—The Definition and Acceptance

The definition for hands-on science is, "Students purposefully manipulating real science materials when safe and appropriate in a way similar to a scientist." The definition has the following five parts:

1) students
2) purposefully manipulating
3) real science materials
4) when safe and appropriate
5) in a way similar to a scientist.

The definition was developed over time in a three-step refinement process:

1) The initial definition of hands-on science was developed and refined by the author and used over approximately five years in her science methods courses for pre-service teachers and science leadership courses for in-service teachers.
2) Before adopting this and the other definitions, the definitions were reviewed and discussed with nine VISTA leaders at the six universities participating in VISTA. The

hands-on science definition was not changed by the VISTA leadership, whereas the other definitions were expanded.

3) Lastly, the definitions were reviewed by eight additional university science education faculty and thirteen school division science coordinators from across Virginia who were participating in the VISTA leadership academies. At this point, the word "purposefully" was added to the definition.

Results—Clarifying Examples and Non-Examples

Before clarifying examples were discussed during professional development, the teachers or leaders were asked: What percentage of time should be spent by students doing hands-on science? After thinking individually, the participants discussed this in small groups of four, and then shared with the whole group. Subsequently, the initial NSTA recommendation that students should be engaged in hands-on learning at least *50%* of the time was shared. Now, NSTA is moving toward describing more what the laboratory investigations should look like on a weekly basis than a particular percentage of time. However, NSTA explicitly states that middle school teachers should "engage students in laboratory investigations a minimum of 80% of the science instruction time" [16].

To refine the teachers' understanding of hands-on science, we found it is necessary for them to classify a series of examples and non-examples of hands-on science. To describe the progression of examples, we use a *PowerPoint* presentation with pictures (see Table 1). For each example, the teachers are asked to evaluate and defend their answer to the question: Is this hands-on science? They do this analysis (see Figures 1 and 2) individually, and then discuss in a small group before sharing with the whole class. Lastly, when teachers have trouble giving up their favorite activities when they don't meet the definition of hands-on science, we come back to the NSTA recommendation which is that less than 100% needs to be hands-on science. This allows them to do their favorite activity, but not count it as hands-on science.

Table 1
Is This Hands-on Science?

Example	Analysis	Hands-on Science
Using silk flowers to study plants	Not real science materials. Not in a way similar to a scientist.	No
Using paper models to represent the parts of a cell, the layers of the earth, DNA,	Not real science materials. Not in a way similar to a scientist.	No

etc.		
Using a computer simulated pendulum lab	Not real science materials. A string and a mass is easy to obtain and use. Students remember what makes a difference with real materials, not on computer. Not in a way similar to a scientist.	No
Using a computer to analyze images of celestial objects	Real computer images of planets are real science materials. Scientists study planets using real pictures, since they can't go there.	Yes

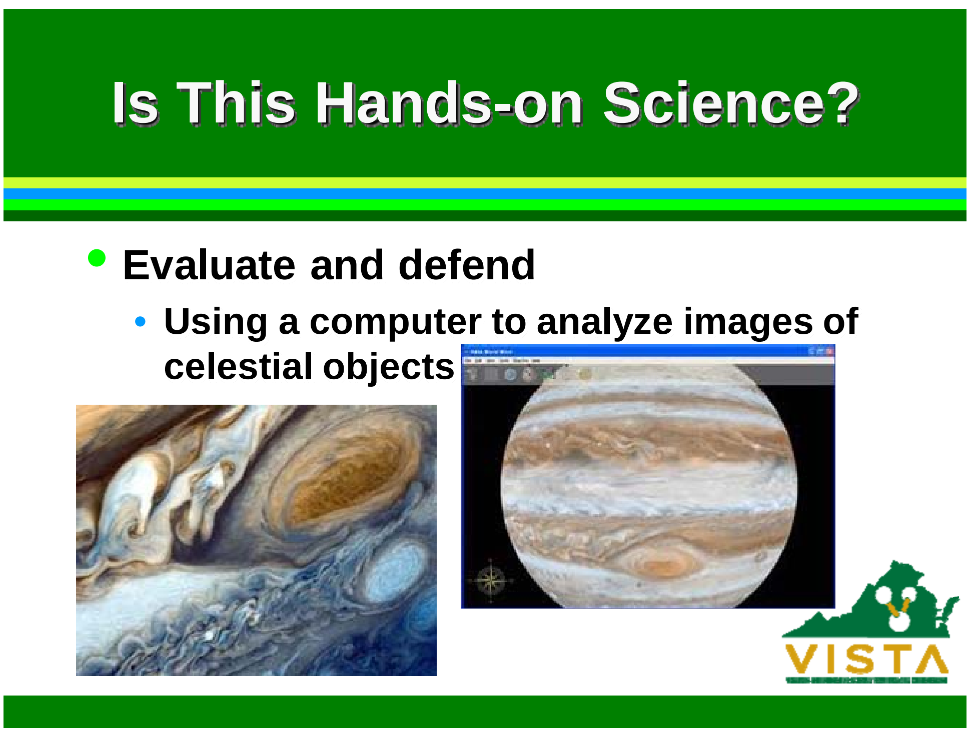

Figure 1. Presentation slide showing an example of hands-on science.

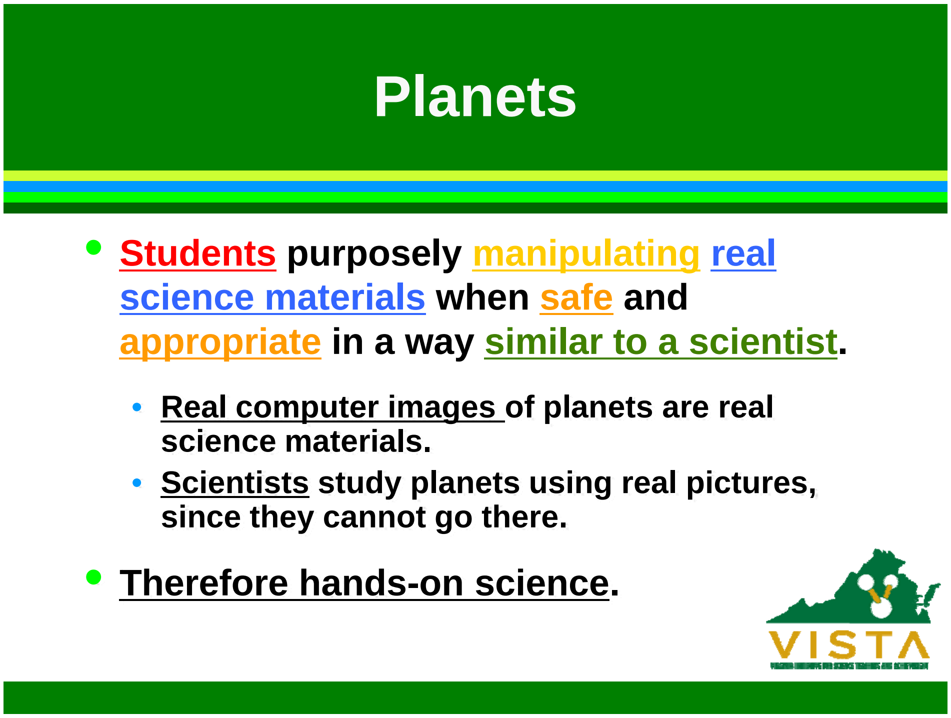

Figure 2. Presentation slide showing explanation for computer planet example.

Hands-on Science Demonstration

The apple lab strongly makes the point that using real science materials when they are available helps the students learn more. In this lab, participants observe three images/models of an apple, and then compare what they can observe from each image. First, the participants are given a picture of a real red apple and asked to write down everything they can observe about it (see Figure 3). Second, the participants are given a realistic model of a red apple and asked to write down everything they can observe about the apple. Third, the participants are given a real red apple and a plastic knife, and asked to write down everything they can observe about the apple. Each time, the list of observations gets longer (see Table 2). The lab is concluded by having a discussion about which form of the apple provided the most information. The participants should easily recognize that their lists were longer as they progressed from the picture, to the model, to the real apple and therefore, their lists were more detailed for the real apple. Thus, the teachers conclude that students should use real science materials as much as possible because the amount of learning is significantly greater.

Figure 3. Picture of a real red apple.

Table 2
Observations of Three Different Depictions of an Apple

Apple	Observations
Picture of a real red apple	Red Round One brown long thing sticking out
Model of a real red apple	All above plus: Sphere Red all over One brown toothpick-like long thing sticking out about 2 cm Balances on one side (bottom)
A real red apple	All above plus: Red all over with slight red variations Light colored yellowish dots all over the outside skin Brown stem Smells sweet White inside Tastes sweet Juicy Small dark seeds in the middle Clear hard flexible pieces surrounding seeds

As needed during the apple observation activity, the difference between an observation and an inference is discussed. It is typical for students to make inferences for which they have no direct observations. For example, you can't observe the apple is white inside until you have the real apple and cut into it. In the picture or model, it is an inference that it is white inside, not an observation.

Assessing Instruction

A rubric was developed to assess a teacher's implementation of hands-on science in teaching (see Table 3). The rubric was designed to assess the five parts of the definition. Initially, the rubric was used by a teacher to assess another teacher's lesson for hands-on science teaching. This approach helped the teacher become more familiar and proficient about the nuances of each aspect of the rubric. Then, the rubric was used by other program participants on each other. This way, the teachers each grew in their proficiency of interpreting each aspect of the definition of hands-on science. A unique aspect of using the rubric was for the teacher to use the rubric on others before it was used on them. This enabled them to use their growing understanding of hands-on science before they designed a hands-on lesson that was critiqued by others using the rubric.

Table 3
Hands-on Science Rubric

Hands-on Students purposefully manipulating real science materials when safe and appropriate in a way similar to a scientist.						
Students are…	Not Observed	Rarely Observed	Occasionally Observed	Often Observed	Consistently Observed	Evidence
…conducting the activity.	0	1	2	3	4	
…purposefully manipulating materials.	0	1	2	3	4	
…using real science materials.	0	1	2	3	4	

…using materials in a safe & appropriate manner.	0	1	2	3	4	
…working in a way similar to a scientist.	0	1	2	3	4	

Discussion

Leaders are most effective when working collaboratively toward clear, common goals. It takes leadership skills and planning to build a common language for all participants in a teaching reform program. Identifying and defining key terms is a crucial, but messy process as consensus is built across the developing learning communities and program. This article outlines a key term, “hands-on science,” needed in one statewide program in Virginia for the improvement of science teaching and student learning. This article shares the definition, the definition development process, the teaching materials created to develop understanding, and the assessment of actual classroom practice. Expectations and accountability measures emerged as key leadership foci.

The school division science coordinators and university science education faculty who participated in the above hands-on science activities as learners not only felt that they developed a deeper and consensus understanding of the term themselves, but that they were also able to use the activities with their pre-service or in-service teachers to develop these teachers’ understanding. In addition, the science coordinators and faculty indicated that they had used the definition and activities for creating a new vision of effective science teaching and for strategic planning. Setting clear expectations and common understanding leads to clearly focused goals for the program and appear to be linked to higher student achievement.

Our findings are consistent with the research on the importance of leadership for setting directions and expectations, and developing teachers’ skills as cited earlier [2, 9, 10]. In general, leaders found that instructionally helpful leadership practices: focused on clear school teaching goals; provided professional development for teachers and leaders aimed at understanding the goals; and, created structures and opportunities for teachers and leaders to collaborate to meet the goals. Clearly defining five parts of the definition for hands-on science clarified important nuances, such as real science materials and using them in a way similar to a scientist. Following this with examples and non-examples focused the teachers and leaders on essential aspects of the definition and provided a platform to discuss and defend explanations, thus building greater understanding. Since implementing effective science teaching in the classroom was a program goal, clearly defining materials to use for learning focused teachers on critical aspects of actually implementing inquiry-based teaching and problem-based learning.

Implications for Policy and Practice

Two implications for policy and practice emerged for leaders from the development of definitions in our study:

1) Program and district leaders need to establish clear expectations across multiple dimensions of improvement activities as the bases for increasing coherence, coordination, and synergy in the effectiveness of statewide and district improvement efforts over time; and,
2) Program and district leaders should combine a common core of communications and support for efforts to implement district expectations with differentiated support aligned to the needs of individuals and programs.

By developing differentiated support for using an explicit definition for hands-on science, program and district leaders, as well as teachers, established a common language for expressing what hands-on science is and is not across the program which increased program coherence and synergy for students to meaningfully investigate science.

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