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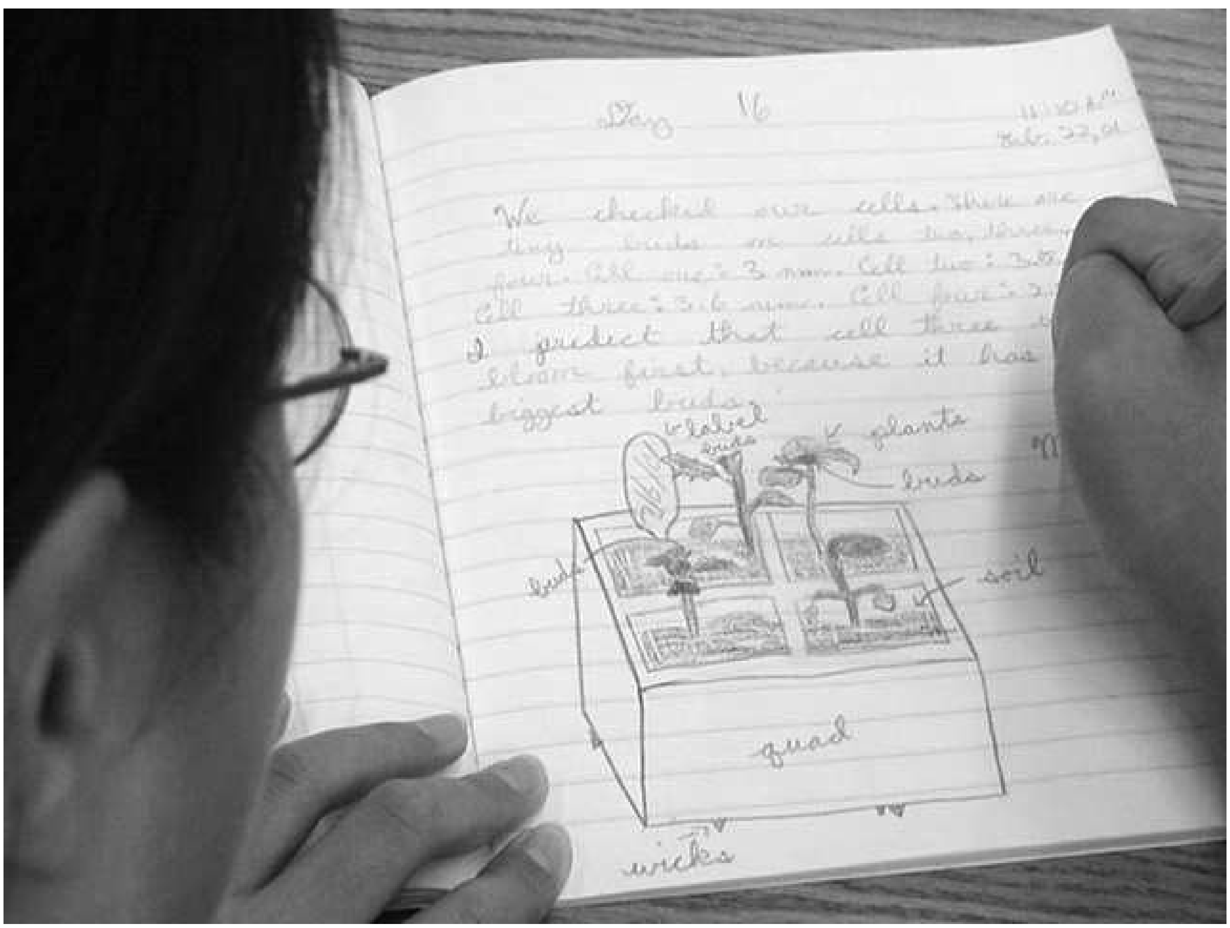

Students' Science Notebooks and the Inquiry Process

Michael P. Klentschy
Elizabeth Molina-De La Torre

Introduction

Public education is currently facing an enormous challenge in the United States. This challenge ultimately may determine the true direction public education will take over the next several decades. There are some that believe that the national movement emphasizing reading, writing, mathematics, as measured by high-stakes standardized tests, threatens to suppress efforts to make progress in science education (Jorgenson and Vanosdall, 2002). School districts are faced with pressure to improve test scores in basic skills and have subsequently reduced or eliminated science instruction in order to attain state benchmarks in these curricular areas. The emphasis of the instructional program is teaching for coverage, rather than teaching for understanding. Educators have argued for years that emphasis on writing as a way of learning may be impossible to implement when models of instruction emphasize the importance of "coverage" of content rather than mutual exploration of interpretations (Langer and Applebee, 1986). Science educators can stem the trend of science being diminished in schools due to the press from policymakers for standards, assessment and accountability in language arts and mathematics by linking literacy and science. A growing number of science educators believe that by making science a key element in strengthening literacy skills, teachers can

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demonstrate that a strong program of instruction science can play an important role in improving achievement in literacy (Thier, 2002).

The Science-Literacy Connection

By linking science and language literacy, science educators can demonstrate the role of science in strengthening student's language skills, thus extending and strengthening the place of science in a basic curriculum. Learning science helps children develop an understanding of the world around them. For this they have to build up concepts that help them link their experiences together and to learn ways of collecting and organizing information and of applying and testing ideas. This learning not only contributes to children's ability to make better sense of things around them, but also prepares them to deal more effectively with wider decision-making and problem solving in their lives. Learning science involves both the processes of thinking and action. When literacy skills are linked to science content, students have personal, practical motivation to master language as a tool that can help them answer their questions about the world around them. Language becomes the primary avenue that students use to arrive at scientific understanding (Thier, 2002). Scientific literacy should emphasize scientific ways of knowing and the process of thinking critically and creatively about the natural world (Harlen, 2001).

The Learning Research and Development Center at the University of Pittsburgh and the National Center on Education and the Economy identifies reciprocal skills associated with science and literacy (2000). These reciprocal skills include the following:

Literacy	*Science*
note details	observe and retain small details
compare and contrast	making notes about the way a variety of substances react to heat
predict	what will happen next
sequence of events	process of logic and analysis
link cause and effect	what causes things to react in a particular way
distinguish fact from opinion	the use of evidence to support claims
link words with precise meanings	develop operational definitions of a concept though experiences
make inferences	based upon observation and evidence
draw conclusions	by combining data from various sources

This analysis of the reciprocal nature of science and literacy strengthens the view that teaching for understanding is a much more powerful means to connect science and literacy. Harlen (2001) suggests that the key to effective science teaching is to enable children to develop ideas about the world around them that fit evidence they have collected and developed personal meaning.

Children bring to new experiences not empty minds ready to be filled with new information, but ideas picked up or created from their past encounters and links they made between the old and new experiences. The learning of science is an active, continuous process whereby the learner takes information from the environment and constructs personal interpretations and meanings based on prior knowledge and experience (Driver and Bell, 1986). Learning involves both a personal and social construction of meaning. In the classroom the child develops cognitively by becoming an agent of their own learning by constructing scientific concepts by drawing on their existing ideas and experience; social interactions mediate knowledge construction; and knowledge is personally constructed by the learner (Shepardson and Britsch, 2001). Harlen (2001) also suggests that learning science also involves students being able to communicate their thinking. This form of communication is oral, written and symbolic in the form of drawings.

Communication is a vital aspect of the process of science. There is a centrality in the power of language in shaping our constructions of the world about us. Words and language are used as a way of trying out a framework for understanding – learners need to have space to reflect on ideas and that space is created through writing. Writing in science is important to generate a personal response to experiences, for clarifying ideas, and for constructing knowledge. Howard (1988) stated, that writing enables the learner to understand first and to communicate second. There is then a link to science and literacy through this social interaction of communication. Vygotsky (1978) concluded that personally meaningful knowledge is socially constructed through shared understandings.

Science and literacy also have another strong point of connection through the desire of many educators to develop metacognitive awareness in children. Cognition is an interactive-constructive process and metacognition is a conscious awareness and control of this process that results in verifying, rethinking, reflecting, and reshaping information into meaningful knowledge networks.

Metacognition often takes the form of an internal dialogue. Many students may be unaware of its importance unless teachers explicitly emphasize the processes. Research has demonstrated that children can be taught these strategies, including the ability to predict outcomes, explain oneself in order to improve understanding, not failures to understand, and to plan ahead (National Research Council, 1999).

Strategies for writing are metacognitive in that they are designed to help students reflect on the process of writing. Thier (2002) suggests that metacognitive activities take students beyond basic performance to deeper levels of reflection and personal understanding. These metacognitive activities may be introduced to students through the completion of open responses such as:

What really surprised me about this activity was….
The outcome of this activity was different from …(another activity) because….

Teaching metacognitive strategies in context has been shown to improve understanding in physics, written composition and problem solving, especially when language skills and science are taught in the context of each other (National Research Council, 1999).

The Valle Imperial Project in Science (VIPS)

The Valle Imperial Project in Science (VIPS) is a NSF funded Local Systemic Initiative serving approximately 27,500, K-8 students and 1200 teachers in 14 school districts in Imperial County, California. Imperial County, located in the southeast corner of California along the United States border with Mexico is both one of the largest (4597 sq. mi.) and most sparsely populated (130,000) counties in California. Located in the extreme southeast corner of the state, the county lacks any large metropolitan area and residents must travel to San Diego (120+ miles) or Los Angeles (200+ miles) to the nearest urban areas.

Many Imperial Valley residents live in extreme poverty, with household incomes declining in real dollars over the last decade. The IRS reported a 2000 mean per capita income of $16,353, the lowest of all California counties. The county's unemployment rates increased from 17.1% in 1991 to 33.2% in 2000, while statewide unemployment rates remained fewer than 5.2%. Imperial County ranks highest in poverty of all 58 counties in California.

Most Imperial Valley residents have strong cultural and linguistic ties to Mexico. Of the 22,500, K-6 students in the Imperial Valley, 81% are Hispanic. Caucasian (11%), African-American (5%), Asians (1%) and Native Americans (1%) make up the rest of the population. More than 50% of the students in the county are Limited English Proficient, with 10% children of migrant workers. Nearly all of the county's schools qualify for Title I. Countywide, more than 67% of all students are eligible for free and reduced lunches.

The science reform model implemented in the Imperial Valley is based on the National Science Resources Center – LASER Model for systemic reform with five critical interrelated elements necessary for effective reform (National Academy of Science, 1997). These elements include: 1) high quality curriculum; 2) sustained professional development and support for teachers and school administrators; 3) materials support; 4) community and top level administrative support; and 5) program assessment and evaluation.

The Valle Imperial Project in Science began in the summer of 1998 as a collaborative partnership between the fourteen Imperial County school districts and San Diego State University, Imperial Valley Campus. It was preceded by three years by a pilot effort on the part of the El Centro Elementary School District, which with 6500 students is the largest district in the county. The pilot program established three pilot schools, a fully functioning materials resource center and developed a cadre of lead teachers. This pilot school effort was the result of the El Centro Elementary School District participating as a member of the National Science Foundation funded Pasadena Center Program at the California Institute of Technology. Direct technical assistance and support was provided by the Pasadena Center to build capacity within the district for future district-wide and countywide expansion of the program.

The design of the Valle Imperial Project in Science links science and literacy through the use of student science notebooks. The inquiry-based model of science instruction is based upon the belief that students need to be provided with an opportunity to develop "voice" in their personal construction of meaning of the science phenomena. This "voice" comes in the form of their science notebooks. The science notebook is utilized during their science experiences, in social interactions, as a tool for reflection, and as a tool for constructing meaning. There is a pattern of significant growth in student achievement in both science achievement and in reading and writing achievement for all students participating in this program (Amaral et al, 2002; Jorgenson and Vanosdall, 2002). Student science notebooks have played an important part in the documented success of this program. Student science notebooks are viewed as knowledge-transforming rather than knowledge-telling. Science has become an important vehicle to extend literacy for the students of Imperial County.

In order to examine the impact on student achievement, it is important to examine the context that student science notebooks play in the inquiry-based program of science instruction; the importance of student "voice" in a knowledge-transforming context; and the importance of feedback.

Student Science Notebooks

The use of writing as a vehicle to promote learning is consistent with the belief that the writer is engaged in active reprocessing at the level of concepts and central ideas (Scardamalia and Bereiter, 1986). Writing is, first, a process of polishing one's thinking for self-edification and, second, communicating those thoughts to others (Howard and Barton, 1986). Writing is a heuristic device with which students can achieve powerful insights and understandings about content (VanDeWeghe, 1987). Writing enables students to express their current ideas about science content in a form that they can examine and think about. Writing is then a symbolic activity of constructing meaning and a tool of understanding as well as communication. The first goal of writing is to understand. Writing is an instrument to think with. Written reasoning to discover or construct meaning must consider purpose, genre and evidence. Written words provide cues for expressing ideas verbally to others. Achievement in science is directly proportional to the student's ability to use language (Fellows, 1994).

Children construct models of the workings of written language by interaction with people and objects in their environment. They simultaneously construct understandings of science phenomena that may be reflected in both their writing and drawing (White and Gundstone, 1992). This view establishes a foundation to an approach to teaching wherein children learn science by doing science and use writing as part of their science experiences. This suggests that in the context of science activities student-produced science notebooks promote the use of literacy while clarifying students' emerging theories about science phenomena (Neuman and Roskos, 1993). How children interact with peers and the products they create – drawings and writings are the means they use to create understandings of science (Doris, 1991).

The Valle Imperial Project in science holds a belief that student science notebooks are a very special, essential means of communication. Student science notebooks used well give not only stability and permanence to children's work, but also purpose and form. They are a record, an extension of their mental activities, paper memory, a store of personally valued information. This form of writing may also help students link new information with prior knowledge (Rivard, 1994). Science notebooks can also contain drawings, tables or graphs that are essential in forming meaning for the child from the science experience. The earlier children start to learn to keep records, the better they will be prepared to make this a natural part of their science activities (Harlen, 1988). Children will recognize this from experiences that require them to keep collect and interpret times and distances or data on other measurements. The use of student science notebooks in class discussions helps students construct meaning of the science phenomena (Harlen, 2001). Teachers from the Valle Imperial Project in Science begin the use of student science notebooks as early as Kindergarten.

The student science notebook then becomes more than a record of data that students collect, facts they learn, and procedures they conduct. The science notebook also becomes a record of students' reflections, questions, speculations, decisions and conclusions all focused on the science phenomena (Thier, 2002). As such, a science notebook becomes a central place where language, data, and experience operate jointly to form meaning for the student. Students written ideas provide a window into their thinking process.

Thier (2002) offers two guiding questions to assist students in internalizing what they learn:

What new ideas do I have after today's activity?

How can I use what I have learned in my everyday life?

Using writing tasks that engage students in reflecting upon their own alternate conceptions, in reconciling them with available evidence and current conceptions might be an effective classroom strategy for enhancing conceptual change (Fellows, 1994). It is in this context that the Valle Imperial Project in Science views the role of student science notebooks as a powerful tool in the learning process of each student.

Discrete knowledge should not be learned for its own sake. Students should be challenged to use this knowledge in solving meaningful problems. Student science notebooks can serve as the medium for fleshing out responses to complex problems requiring higher order reasoning. The way that writing is employed and evaluated in the classroom is critical in determining students' perceptions of its potential for learning content (Rivard, 1994). By creating their own science notebook pages students are able to describe their ways of seeing and thinking about the science phenomena, constructing and reconstructing meaning through their own lens of experience (Shepardson,1997). This construction of meaning is done in the "voice" of the student, not the teacher.

The Valle Imperial Project in Science has an established belief that students need time to develop the skill of self-expression and recording their observations. In the earliest stages, children may use their notebooks only to draw what they see and what they think is going on. This early use of drawings is an important beginning if students are expected to record their observations in some way, they are likely to observe more closely and shed their preconceptions and see what is really there (Harlen, 2001). Later student science notebooks become useful instruments for recording what they do in their investigations and the results they achieve. The professional development program for teachers in the Valle Imperial Project in Science is designed to develop a “best practice” where the teacher guides the students to record what they actually see and do, not what they think the teacher expects them to see or do.

Vygotsky (1978) referred to drawing as graphic speech and noted that young students' representations often reflect what they know about the object more that what is actually perceived. These drawings can act as a guide to student’s understandings. Students incorporate different selections of such details in order to draw the experience into a content that makes sense to them. Drawing and writing produced in a science investigation are valuable because they allow students to express their ideas and findings; they take the role of talk with regard to assisting students in making meaning of their ideas (Harlen, 1988). It is in this context that the Valle Imperial Project in Science views the use of student drawings as an important aspect in developing the science-literacy connection for all students.

The nature of student’s contextualization of the science phenomena and the activity on the science notebook page are dependent on the student’s familiarity with the phenomena and equipment and length of exposure to the program of instruction (Amaral et al, 2002). In unfamiliar situations the student’s entries reflect the immediately observed science investigation, whereas in familiar situations the children’s entries are based on their experiences with the phenomena, placing the science investigation into a real-world context (Shepardson, 1997). In an analysis of the initial use of student science notebooks in the Valle Imperial Project in Science, the students’ first science notebooks took on the form of a narrative or procedural recount (Amaral et al, 2002). One caveat about the use of science notebooks, however, is that while they may engage students in solving problems, they less frequently engage students in finding problems (Reddy et al., 1998). While students may be quite interested in and excited about carrying out science activities, they may not be willing to spend time interpreting their results. Students' self produced journal pages may be viewed as a story that unfolds as the observed phenomena change over time, a story molded to fit the children's way of seeing; therefore the story may be distorted from that of a scientist or a teacher (Shepardson, 1997). This action is developmental and teachers must guide students to be more reflective about their work. Student science notebooks have the potential to move students beyond simply completing the task to making sense of the task. In this way these science notebooks can support the development of students' scientific thinking.

Knowledge-Transforming

Langer and Applebee (1986) reported that students are more aware of their strategies, rhetorical structures and background knowledge while writing than while reading. Strategic and text-structure usage are not as easily apparent to readers as they are to writers. The act of writing by its very nature may enhance thinking. Writing may achieve this by demanding the learner to organize language. Much classroom writing is mechanical and the student is passive in their role. Frequently classroom writing in science is directed at communicating what the writer knows to the teacher as an informed audience, filling in the blanks or producing short responses to teacher-generated questions and recording observations and information (Applebee, 1984). In the elementary science curriculum student science notebooks have served primarily as logs in which children simply maintain records of experiments and list results. Simply logging the results and listing the experiments limits students in the construction of true meaning from the phenomena and reduces the experience to a knowledge telling type of experience. Shepardson and Britsch (2001) concluded that the student's entry on the science notebook page must function as more than a means of reporting teacher expected results. This type of writing emphasizes knowledge telling, production of text, uninteresting tasks and transmission of recalled information. The role of writing directed to oneself is limited.

The use of student science notebooks is effective for most students when the teacher is more concerned with establishing a dialogue with students to monitor learning, emphasizing the thinking and learning processes involved in learning the content (Willey, 1988). Bereiter and Scardamalia (1987) described two types of writing: knowledge telling and the less well-considered knowledge-transforming mode. The dominant use of the knowledge-telling mode may have an adverse effect on how children organize and store knowledge because it is a simplistic strategy that diminishes students' ability to reorganize their knowledge. The interactive-constructive processes involved in the knowledge-transforming model of writing parallels the constructivist model of science learning in that involves long-term memory, working memory and sensory motor activity. The knowledge-transforming model may be far more interactive and recursive than linear.

In the Valle Imperial Project in Science, teacher professional development in the use of student science notebooks guides teachers to pose questions which students might ask themselves in knowledge-transforming writing in their science notebooks such as:

What evidence do I have?

What claims should I make?

What are alternative explanations?

Santa and Havens (1991) suggested that meaningful writing should bridge new information and prior knowledge, provide authentic authoring tasks for an uninformed audience, encourage minds-on learning, facilitate conceptual organization and restructuring, and promote metacognition. Writing should allow the transformation of vague ideas to clear conceptions and stimulate the construction of meaning. These are the shared beliefs of the Valle Imperial Project in Science through the use of student science notebooks. This belief is also based on the importance of establishing student "voice" in science notebook writing. Only the student can fully understand the importance, difficulty and thinking involved in transforming experiences into abstract symbols and then constructing meaning from the process or knowledge-transforming. This form of writing is clearly different than knowledge telling.

Palinscar and Magnusson (2000) reported that students participating in inquiry-based science found the presence of "voice" in the notebook text of a fictitious scientist, Lesley Parks, that was introduced as a second hand experience used in conjunction with the students' first-hand inquiry-based experience on the properties of light. The notebook text influenced the students' thinking when they conducted their own first-hand inquiry-based investigations on the properties of light following their secondhand investigation of reading the notebook text. The students were challenged in distinguishing among evidence, claims and data. The students were very attentive to the organization and representation of their data, drawing heavily on the formatting ideas presented in the scientist's notebook in their own work. The presence of "voice" may well be an important factor in constructing meaning for students. The Valle Imperial Project in Science is currently examining the impact of the combination of "voice" in secondhand text along with providing students with opportunities for knowledge-transforming writing in the form of science notebooks on student achievement in science and literacy.

Holliday et al (1994) described the need to emphasize knowledge-transformation models that embody evidence, reasoning, interpretation and thinking. Such a mode of writing emphasizes exploration, expressive inquiry, decision-making, and knowledge construction. It is a process of constructing understanding, enhancing personal clarity, and producing insightfulness. Hanrahan (1999) reported that this type of writing encouraged students to participate in their own learning. Caswell and Lamon (1998) found that when fourth grade students were exposed to inquiry and used their own science notebooks instead of completing teacher created products, the amount of writing the children did increased; students did more than simply observe and were more involved in the investigation. The students' science notebook writing enabled them to organize collected information in novel ways, to develop hypotheses and to interpret and explain on the basis of collected information. Similar findings have been reported with regard to student writing accomplishment in the Valle Imperial Project in Science (Jorgenson and Vanosdall, 2002). Marzano (1991) has argued that fostering higher order thinking demands instructional activities in which the learner's existing knowledge is restructured through activities that are complex and long term. He argues that writing is appropriate to induce knowledge transformation.

Shepardson and Britsch (2001) reported that students frame their understanding of science investigations and phenomena with reference to three types of mental contexts that may be reflected graphically on the pages of their science notebooks. These contexts are their imaginary, experiences and investigative worlds. By drawing upon these three internal contexts, the children were able to pull an external phenomenon into an internal context that was familiar to them. This internal context linked with the science experience to frame a way of thinking that used the student's prior knowledge and experiences to construct science understandings. The science notebooks must allow students to use various student-selected combinations of writing and drawing to construct and represent their understandings with flexibility in their use of genre. This enables the student to use science notebooks in ways that are both socially and cognitively appropriate to their developing understandings of science phenomena and are thus knowledge-transforming. It is in this same context that the Valle Imperial Project in Science utilizes student science notebooks as a knowledge-transforming device for students.

Feedback

One of the most important strategies a teacher can use is to provide students with feedback on their work. Teacher feedback plays an important role in the knowledge-transformational process of using student notebooks in inquiry-based science instruction. The role of the teacher in the knowledge-transforming process takes on a different form than from the knowledge-telling. Marzano et al (2001) reported in a review of nine research studies that feedback that guides students, rather than telling them what is right or wrong on a test can attain an effect size of .90 or higher. The most appropriate form of feedback in a knowledge-transforming mode of instruction is one of asking guiding questions to the student or writing guiding questions in their science notebooks. The feedback can also take the form of a personal written conversation between the teacher and the student in the student's science notebook. In the Valle Imperial Project in Science, professional development activities for teachers in the use of student science notebooks in their classrooms stress this form of feedback. This form of feedback can best be summarized as "issues, evidence and you." For example:

What evidence do you have to support your claims?

What claims can you make from your evidence?

Is there another explanation for what happened?

The timing of feedback also appears to be critical to its effectiveness. In general, the more delay that occurs in giving feedback, the longer it takes students to clear misconceptions (Marzano et al, 2001). This could be especially true in clearing science misconceptions reported by Shepardson and Britsch (2001). Not only should feedback be timely, it should also reference a specific developmentally appropriate level of skill or knowledge expected of students. Research has consistently indicated that this form of feedback has a more powerful effect on student learning than simply reporting to students their standing in relation to their peers (Marzano et al, 2001). These strategies and techniques are used extensively in the Valle Imperial Project in Science through the use of developmental "storylines" for each of the units of science instruction. The developmental "storylines" serve as a graphic organizer that establishes a flowchart indicating the "big idea" or unifying concept of each unit of study (Amaral et al, 2002). These form the basis for a rubric used by teachers in providing appropriate written feedback to students in their science notebooks.

Research on feedback also indicates that students can effectively monitor their own progress (Marzano et al, 2001). The use of student feedback in the form of self evaluation has been strongly advocated by researcher Grant Wiggins (1993). Using the Valle Imperial Project in Science rubric for student science notebooks, teachers have students utilize the rubric during classroom discussions of their experiences, evidence and claims related to the science phenomena they are investigating. This self-evaluating form of feedback is also important in the construction of meaning by the students.

Summary

Educators across the United States are feeling the press of standards, assessment and accountability. Increasingly, time is being squeezed from the instructional day in an attempt to strengthen student achievement in reading, language arts and mathematics. As a result science has almost become an invisible curriculum in many classrooms. Yet at the same time there is a growing body of evidence that indicates a strong relationship between students participating in effective programs of inquiry-based science instruction not only improving their achievement in science, but also in reading, language arts and mathematics (Amaral et al, 2002, Jorgenson and Vanosdall, 2002). An extensive examination of this body of evidence indicates that there is a strong connection between science and literacy. Each discipline reinforces the other discipline. It is a reciprocal process. This connection appears to be the strongest where student science notebooks play a pivotal role in the instructional program. This connection also has the potential to assist students in developing their metacognitive abilities in science.

The student science notebook serves as the important link between science and literacy when it is utilized in the classroom as a knowledge-transforming form of writing provides the appropriate opportunity for students to develop “voice” in the process of constructing meaning from their experiences with the science phenomena. This coupled with appropriate and timely feedback from the classroom teacher has strong potential to provide the improvement in student achievement educators are seeking. As a nation, we must examine the consequences of reducing or even eliminating science instruction from our classrooms for the sake of raising test scores in other curricular areas. This action will be a missed opportunity that the current generation of students, and the nation, may never recover from educationally and economically.

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