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Science Education and Literacy: Imperatives for the Developed and Developing World

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PERSPECTIVE

Science Education and Literacy: Imperatives for the Developed and Developing World

Paul Webb

This article explores current language-based research aimed at promoting scientific literacy and examines issues of language use in schools, particularly where science teaching and learning take place in teachers' and learners' second language. Literature supporting the premise that promoting reading, writing, and talking while "doing science" plays a vital role in effective teaching and learning of the subject is highlighted. A wide range of studies suggest that, whether in homogenous or language-diverse settings, science educators can make a significant contribution to both understanding science and promoting literacy.

There is concern around the apparent inability of science education to counter current negative perceptions of science in both developing and industrial countries (*1*). These concerns have resulted in consensus within the science education community over the past five decades that there is a need to focus on science literacy. The framework within which this consensus initially developed emphasized scientific knowledge and applications. However, a more recent consensus that has emerged within sectors of the science education community is the need to focus more on the literacy aspects of science literacy (*2*, *3*). Norris and Phillips (*2*) draw a distinction between the fundamental and derived senses of science literacy in that the fundamental sense requires proficiency in science language and thinking, whereas being proficient in the derived sense means being able to make informed judgements on scientific societal issues (*4*).

A number of researchers (*2*, *5*) believe that for someone to be judged scientifically literate in both the fundamental and derived senses, he or she must be first proficient in the discourses of science, which include reading, writing, and talking science. In order to achieve these goals, students must be helped to cross the borders between the informal language they speak at home and the academic language used at school, particularly the specialized language of science (*5*). Furthermore, there are many situations where the teaching and learning of science takes place in a second or foreign language. Many previously Anglophone colonial states in Africa choose English as the language of teaching and learning in their schools because it is seen as the language that best provides access to economic and social mobility. In these and many other countries, issues of language are exacerbated by the fact that often both teachers and learners are second-language speakers in terms of the language of teaching and learning in their schools (*6*). It is within the above contexts that this paper reviews language-based strategies aimed at promoting science literacy.

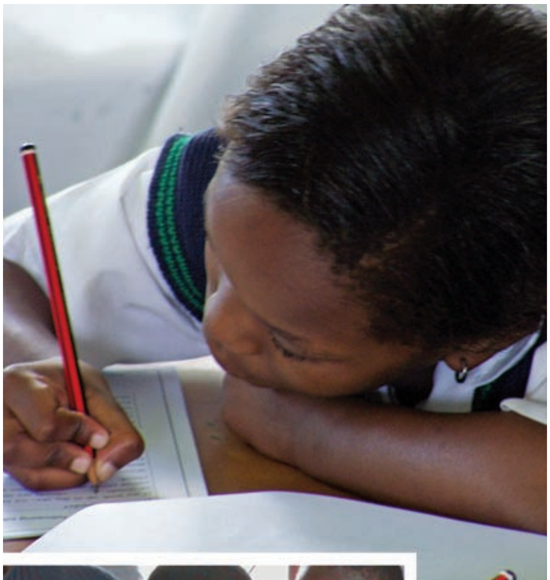

Fig. 1. **(Top)** Writing to learn science. **(Bottom)** When the light goes on: thinking about science.

Integration of Language and Science Studies

The uncritical belief that hands-on science activities automatically lead to understanding has been replaced with the realization that this is a necessary, but not sufficient, approach. What is needed are minds-on experiences that include discussion, planning, reading, and writing, as well as deliberations and argumentation. One of the first programs that explored the integration of language and science instruction introduced a science-content reading program emphasizing inquiry activities, science processes, and the comprehension of written information provided for the topic at hand (*7*). The result was that both reading and science scores improved, as well as student attitudes toward science. Further efforts, which included science writing in a large number of elementary and middle schools in two very large school districts, resulted in similar findings (*8*, *9*). Other researchers have also shown the value of reading to learn science. Cervetti *et al.* (*10*) built and tested a curriculum that used literacy instruction to help students acquire the knowledge, skills, and dispositions of inquiry-based science, an approach that also saw students making significant gains in terms of both literacy and science.

In the El Centro district in California, a science kit–based writing program was developed for low socioeconomic elementary schools with a high percentage of English second-language learners (*11*). The results of a large-scale study (over 1100 students) revealed significant improvements in grades four and six science achievement and grade six writing in English. In another study (*12*), professional development was provided that integrated literacy, science, and mathematics across five school districts. The grade five students of teachers who participated in this program achieved higher scores for reading, writing, mathematics, and science, and it was shown that improved student performance was significantly affected by teacher beliefs and classroom practices. Hand (*13*) used an approach that required learners to pose questions, make claims supported by evidence, consult with experts, and reflect on changes that they made to their original thinking. The Science Writing Heuristic (SWH) approach represents a move from laboratory work as recipes and simple report writing to meaningful writing toward sense making by integrating understandings of the nature of science, scientific inquiry, and issues of argumentation. Hand's (*13*) research showed great benefits to students, and a meta-analysis of six quantitative studies (*14*), as well as a meta-synthesis of 10 qualitative studies (*15*), revealed consistently positive evidence for the SWH ap-

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proach across science topics and at all educational levels (primary school to university).

Science and Second-Language Learners

Research has shown that in developed countries real benefits accrue from developing native language literacy when working with English-language learners (*6*, *16*). There is evidence that, where the home language is neglected in favor of a second language such as English, young learners develop neither language sufficiently (*17*). Similarly, in previously colonized African and Asian societies, where the teaching and learning of science often takes place in a second or foreign language for both teacher and learners, the use of an unfamiliar European language often results in restricted teaching methods and poor student achievement (*18*). Conversely, when Haitian-Creole students were encouraged to use the vernacular to discuss topics in science, both their conceptual understandings and their capacity to recognize established relationships between claims and evidence improved (*19*).

In the South African context, where most parents and teachers tend to choose English instruction for their children because it is perceived to be the language of socio-economic power and mobility, the teachers do most of the talking while children understand little and remain silent and passive (*16*). These children's performance in national and international tests of science, literacy, and numeracy is exceptionally poor (*17*). In contrast, studies in Nigeria and Zambia have revealed that better results were produced in schools where mother tongue instruction was continued until secondary level and have shown that too early an emphasis on English impairs children's subsequent learning (*18*). Consistently poor South African results, as well as well-researched arguments around language use in schools, have stimulated South African studies that investigated the talking, writing, and arguing aspects of science in elementary and middle schools (Fig. 1). These investigations included research on classroom discussion (*20*), use of the "science notebook" approach (*21*), and argumentation (*22*). All of the studies incorporated the use of students' native language and produced encouraging results in terms of improved problem-solving, science, and argumentation skills, respectively.

These South African findings resulted in the development of an approach (*23*) that aimed to integrate reading to learn science and learning to read for science; exploratory talk toward investigable questions, planning, and doing an investigation; and scaffolded writing to learn science, argumentation, and critical thinking. The basic tenets of the model are illustrated in Fig. 2.

The stimulus (the reading material, discrepant, or unexpected event, etc.) provides the stimulation for discussion but can also help access information needed to raise investigable and researchable questions. The discussion and the investigable question generated provide the framework for planning and executing the investigation, whereas the data generated are recorded in a science notebook (*24*). Once the line of learning is drawn in the children's science notebook—that is, they have drawn all the conclusions that they can from their classroom investigation—further reading and research allows them to go beyond the limits of their investigatable question. This means that they can explore the noninvestigatable but researchable questions that were raised as part of their earlier discussions through other forms of information gathering. Lastly, getting students to record their arguments within an argumentation writing frame provides an exercise that aims to improve their understandings of the nature of science, scientific processes and procedures, and notion of audience and presentation. When teachers were trained to use the model, issues of bilingualism and code switching were discussed, and they were encouraged to make explicit to their students that they could legitimately discuss, argue, and write in their home language while doing a scientific investigation (*23*).

The model was implemented with grade six teachers and learners in a deep rural area of South Africa where, although the language of teaching and learning in these schools is English, the children and parents rarely hear or speak the language. The results of this 1-year intervention mirrored those of the earlier South African studies described above, but new findings were that the students' English reading skills improved significantly, as did their writing and listening skills in their native language (*23*).

Language and Learning

There are a number of research findings, both in the developed and developing world, that show the benefits of native language instruction for English-language learners (*25*, *26*). In terms of science education, it is suggested that for successful learning to take place attention must be paid to cognitive development in both the language of instruction and the students' native language. One such way of doing this is by teachers code-switching (when possible) and/or allowing children to first make sense of what is expected of them in their home language and then to translate what they understand into the official language of teaching and learning. In turn, there is growing support for the premise that promoting reading, writing, and talking while "doing science" plays a vital role in effective teaching and learning of the subject. In the final analysis, what is important is that, whether in homogenous or language-diverse settings, science educators can make a significant contribution to both understanding science and promoting literacy. As such, they should be encouraged to pay closer attention to

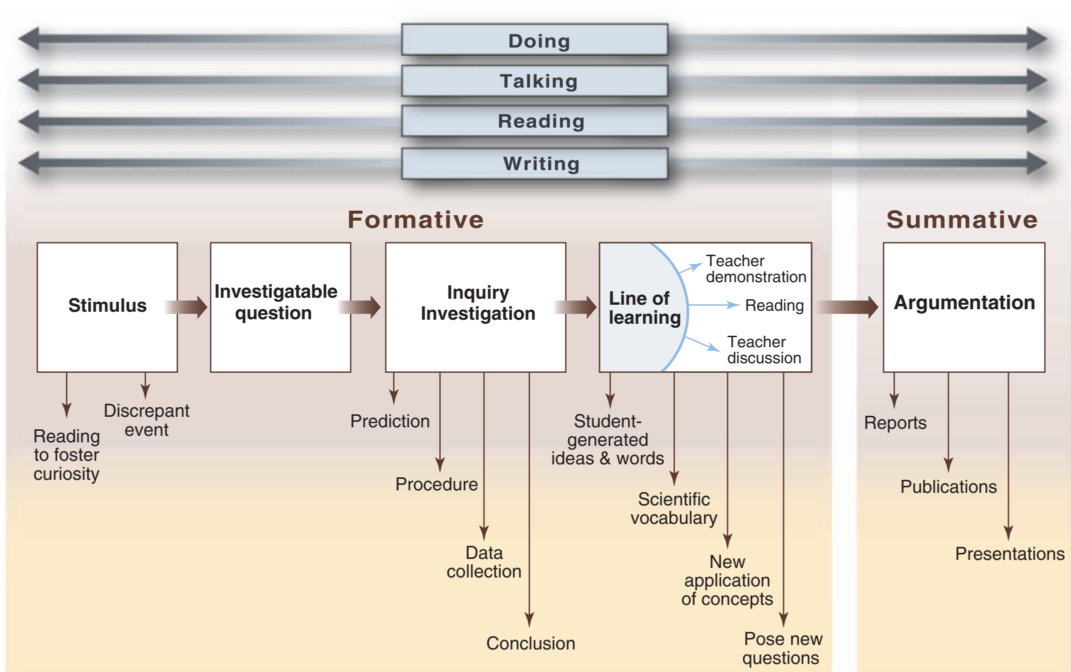

Fig. 2. An integrated strategy for promoting teaching and learning toward scientific literacy.

their learners' struggles to come to terms with unfamiliar language, discourse patterns, and the often formidable conventions of science (*27*).

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PERSPECTIVE

Academic Language and the Challenge of Reading for Learning About Science

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A major challenge to students learning science is the academic language in which science is written. Academic language is designed to be concise, precise, and authoritative. To achieve these goals, it uses sophisticated words and complex grammatical constructions that can disrupt reading comprehension and block learning. Students need help in learning academic vocabulary and how to process academic language if they are to become independent learners of science.

Literacy scholars and secondary teachers alike are puzzled by the frequency with which students who read words accurately and fluently have trouble comprehending text (*1*, *2*). Such students have mastered what was traditionally considered the major obstacle to reading success: the depth and complexity of the English spelling system. But many middle- and high-school students are less able to convert their word-reading skills into comprehension when confronted with texts in science (or math or social studies) than they are when confronted with texts of fiction or discursive essays. The greater difficulty of science, math, and social studies texts than of texts encountered in English language arts (mostly narratives) suggests that the comprehension of "academic language" may be one source of the challenge. So what is academic language?

Academic language is one of the terms [others include language of education (*3*), language of schooling (*4*), scientific language (*5*), and academic English (*6*, *7*)] used to refer to the form of language expected in contexts such as the exposition of topics in the school curriculum, making arguments, defending propositions, and synthesizing information. There is no exact boundary when defining academic language; it falls toward one end of a continuum (defined by formality of tone, complexity of content, and degree of impersonality of stance), with informal, casual, conversational language at the other extreme. There is also no single academic language, just as there is no single variety of educated American English. Academic language features vary as a function of discipline, topic, and mode (written versus oral, for example), but there are certain common characteristics that distinguish highly academic from less academic or more conversational language and that make academic language—even well-written, carefully constructed, and professionally edited academic language—difficult to comprehend and even harder to produce (*8*).

Among the most commonly noted features of academic language are conciseness, achieved by avoiding redundancy; using a high density of information-bearing words, ensuring precision of expression; and relying on grammatical processes to compress complex ideas into few words (*8*, *9*). Less academic language, on the other hand, such as that used in e-mails, resembles oral language forms more closely: Most sentences begin with pronouns or animate subjects; verbs refer to actions rather than relations; and long sentences are characterized by sequencing of information rather than embeddings. The two excerpts in Fig. 1, both about torque (a topic included in many state standards for 7th-grade science), display the difference between a nonacademic text (from the Web site www.lowrider.com) and an academic text (from the Web site www.tutorvista.com).

A striking difference between more informal and more academic language exemplified in the Lowrider/TutorVista text comparison is the greater presence of expressive, involved, interpersonal stance markers in the first Lowrider posting ("…guys get caught up…," "I frequently get asked…," "Most of us…,") and in the response

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