Res Sci Educ (2009) 39:313–319
DOI 10.1007/s11165-008-9111-z

Bridging the Gap Between the Language of Science and the Language of School Science Through the Use of Adapted Primary Literature

Linda M. Phillips · Stephen P. Norris

Abstract In this paper we make the case that the language of school science and the language of science are widely divergent. We trace the divergence to a simple view of reading that prevails not only in science education but in most of schooling. Based upon the importance of language in science and the role of language in capturing the essential nature of scientific reasoning, we conclude that conceiving of reading as a form of inquiry could assist in bringing the two languages more into alignment. We recommend the use of adapted primary literature as one curriculum and instruction innovation that can be useful in illustrating the nature of reading as inquiry.

Keywords Adapted primary literature · Scientific language · Scientific literacy · Science reading

Our position is simple to state: When scientists read, they are doing inquiry. Reading as inquiry could become a part of school science instruction. Nevertheless, the case for this position is complicated and the science curriculum and science educators have not been attuned to think of the importance of reading to science (Wellington and Osborne 2001; Yore et al. 1998). Thus, something resembling a radical change in perspective is required in order to make our position work in practice.

In this paper we treat the following topics: the importance of reading and writing to science, the language of science, the language of school science, the nature of reading, and

L. M. Phillips
Canadian Centre for Research on Literacy, University of Alberta, Edmonton, Alberta T6G 2G5, Canada

S. P. Norris (✉)
Centre for Research in Youth, Science Teaching and Learning, University of Alberta,
7-104 Education North,
Edmonton, Alberta T6G 2G5, Canada
e-mail: stephen.norris@ualberta.ca

the prospects of using adapted primary literature in bridging between the language of science and the language of school science.

Reading, Writing and Speaking are Essential to Science

Tenopir and King (2004) demonstrated convincingly the importance of reading to science. According to their data, the scientists they surveyed read a great deal, on average 553 h per year or 23% of total work time. Among the scientists, the award-winning and high-achieving scientists read more than the average. When the communication activities of speaking and writing were included, the scientists spent on average 58% of their total working time in communication. These data provide an indirect indicator of the value the scientists gained from reading, writing and speaking. More directly, the scientists rated reading as essential to their work and as their primary source of creative stimulation.

These are interesting findings. Frequently, science is described as “a hands-on activity”. We read and hear this description when applied to school science, but we also have heard the description used frequently by the scientific community itself. For example, many of our science colleagues working with us on school-based science education research and development projects describe their scientific work as “hands-on” and aspire to this form of work for the school curriculum on the grounds that science teaching so conceived would more accurately represent science. There is, of course, a point to what they are saying. Much of experimental and field-based science *is* hands-on. However, much of science is neither experimental nor field-based, but rather is more conceptual and theoretical and more concerned with ideas than with data. Yet, Tenopir’s and King’s data suggests that describing even experimental science as hands-on, as if that were its primary characteristic, is to misrepresent. It appears that the nitty-gritty, hands-on activity of data gathering is surrounded by an even more pervasive and consuming activity of communication, defined not by the physical but by the mental—reading, writing, and speaking—minds-on activities.

It would be wrongheaded in our estimation to argue that such minds-on activities are not really part of science and that the real science takes place during the physical manipulation and exploration of the natural world. No doubt, science does involve direct contact with the natural world, probing and exploring to determine its structures and functions. It is such an activity that helps to set science apart from metaphysics. Nevertheless, when scientists rate reading as essential to their work, and spend a duration approaching two-thirds of their working hours on reading, writing, and speaking activities, it seems better to concede that the minds-on is as much a part of science as the hands-on and to recognize that much of the minds-on activity is mediated by spoken and written language. So, we conclude:

> Reading and writing are inextricably linked to the very nature and fabric of science, and, by extension, to learning science. Take them away and there goes science and proper science learning also, just as surely as removing observation, measurement, and experiment would destroy science and proper science learning (Norris and Phillips 2003, p. 226).

The Language of Science

Having argued that reading and writing, and the use of language generally, are essential to science, we now turn to the question of the nature of scientific language. Other than specialized technical terms, which are widely seen as emblematic of scientific language, what else characterizes it? Suppe (1998) examined more than 1000 data-based papers in science. He found that the papers from diverse disciplines have a common organizational structure. The papers do the following: present the data arising from observations; show the relevance of the observations to some scientific problem; detail data collection and analysis methods; provide and justify an interpretation of the data; and identify, acknowledge, and possibly impeach specific alternative interpretations. That is, the scientists engage in a variety of speech acts. These speech acts throughout their papers create an argumentative structure that is common to data-based papers in the variety of disciplines examined. The fundamental unit of that structure is a reason offered for something to believe or something to do. That fundamental structure is manifested in a variety of forms, which we have depicted in Fig. 1, namely, justifications offered for problems or questions to study; justifications offered for methods to employ, data to collect, and analyses to conduct; evidence proffered for interpretations of the results; and evidence put forward for the rejection of alternative interpretations of the results.

We have conducted our own analyses of data-based research reports in physics. For example, in a report covering just two journal pages of a study of hysteresis in silica aerogels (Beamish and Herman 2003), we identified a range of speech acts. The authors

- motivated their study
- reported relevant past results
- reported limitations of past research
- described what was done
- argued for the suitability of techniques
- explained observations
- conjectured what might be happening, and
- challenged alternative interpretations.

Similarly to Suppe, we found that the entire article was given to creating a series of arguments (for conducting the research, for the techniques employed, against alternative explanations of the findings) all in the service of supporting the interpretation of the findings that the authors favoured. We examined another article reporting on the transition from crystalline to amorphous solids in certain nanocrystals under the influence of radiation (Meldrum et al. 2002). These authors offered many extended arguments including the following: a full-paragraph case that zirconia is a radiation-resistant ceramic—the point was to signal that the results were unexpected, that previous conclusions will be upset, and that therefore this study is significant; and two justifications for the methods chosen, including a case that the crystals of zirconia that reached the amorphous state were sufficiently small to allow the formation of tetragonal zirconia and arguments against alternative interpretations of their observations based on how various steps of their method made other possible mechanisms implausible.

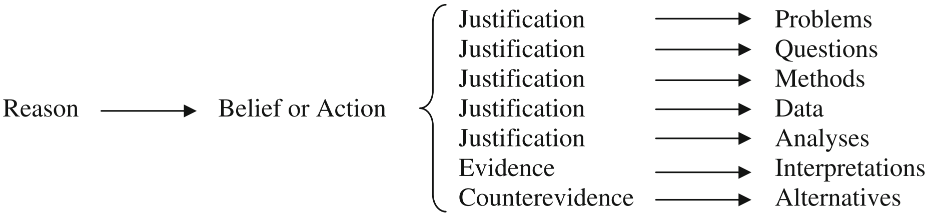

Fig. 1 Various manifestations of the relationship of reasons to conclusions about what to believe or what to do (→ means “offered for”)

Although one of us has a physics background, the specifics of the research reported were very much beyond that background. Nevertheless, and we found this very interesting, the overall argumentative structure of the articles was readily discernible. Our personal experience with these articles suggested to us that Norris (1992) was on the right track when he suggested that one goal of science education should be to teach students to see the "justificatory shape" within science, that is, the shape that the arguments need to take to support given conclusions. Norris was surmising that the specifics of scientific justifications were going to be beyond the grasp of most non-scientists. Nonetheless, they could be taught to grasp the general nature of scientific justifications so that the source of scientific findings would seem less of a mystery.

We thus conclude, as we have argued elsewhere (e.g., Norris and Phillips 1994) that scientific language is textured and structured—textured in that not all of its statements have the same reported or implied truth status (e.g., true, probable, uncertain, false); and structured in that not all of its statements have the same epistemic status and role (e.g., cause, effect, observation, hypothesis, method, motivation). Much of the difficulty interpreting scientific text lies in failure to see this texture and structure and to grasp the implied connections of one statement to another (Myers 1991; Norris and Phillips 1994; Norris et al. 2003). It is our contention that the difficulty is traceable to the language of school science.

The Language of School Science

Let us examine first the language of school science as revealed in textbooks. Although scientific journal articles deal in argument as we have shown, science textbooks and trade books deal primarily in exposition. As Myers (1992, 1997) has shown in a series of studies, textbooks never provide proof, present statements as accredited facts with no hedging, and use illustrations to picture rather than to provide argumentative functions. Even if we wish to hedge Myers' conclusions somewhat to "almost never provide proof", the force of the indictment hardly changes.

Research that we have conducted (Penney et al. 2003) resulted in the conclusions that, depending upon the book, 90% to 99% of the statements in textbooks we examined presented science as truths; the text was either expository or narrative—there was absolutely no argumentative text; depending upon the book and topic, between 51% and 77% of statements provided facts or conclusions; about 2% of space was devoted to what prompted scientific research to be done and 3% to how the research was done; and less than 2% of the text was devoted to providing reasons. In a similar vein, Ford (2005) found that the vast majority of children's trade books were non-fiction accounts of factual information. Any tentativeness in the books was expressed with such subtlety that it likely would be lost on most readers, and scientific knowledge production was represented more as a procedure than as reasoning from evidence.

Although it would be a farfetched and perhaps even misguided hope that school science textbooks and trade books mirror the language of science, it is a well-founded desire that they not so distort science as to make it unrecognizable. When the argumentation that is so central to and emblematic of science is removed altogether, or nearly so, we believe that such a level of distortion has been reached.

Unfortunately, evidence suggests that the language of science classroom instruction resembles the language of science textbooks. Classroom observational studies (e.g., Wignell 1987; Ebbers and Rowell 2002) have shown that the main aim of reading in science classrooms is the students' understanding of relatively isolated technical terms. Recall the research of Tenopir and King showing that reading is the primary source of creative imagination for scientists. The two purposes could hardly be more distinct. Classroom observations also have shown that when students are asked to write at length, they tend to copy passages of text from research materials they have found (Ebbers and Rowell 2002). Contrast this function with the argumentative function of scientific writing. Turning to classroom dialogue, Newton and Newton (2000) and Newton et al. (2002) found that teachers' discourse often is confined to developing vocabulary and descriptive understandings of phenomena and situations. They saw little evidence of an oral press for causal understanding with its persistent emphasis on reasoning, argument, and explanation.

Someone might be prepared to argue that these classroom purposes for reading, writing, and speaking are acceptable because, in the end, they produce the outcomes we desire. We believe the evidence points strongly in the opposite direction. Students are *expected* to read scientific texts by the time they leave elementary school, but they usually have a great difficulty doing so. In a series of studies stretching over a decade (Norris and Phillips 1994; Norris et al. 2003; Phillips and Norris 1999), we have demonstrated patterns of weakness in the reading ability of high school and university science students: they demonstrate a certainty bias, interpreting what they read as expressing more certainty than authors intended; they are weak when interpreting the role of statements in the scientific reasoning; their evaluative positions on the content and implications of what they have read do not follow from a critical assessment of reasons; their beliefs on a topic after reading bear little relationship to the evidence in what was read; when explaining the meaning of what they have read, they tend to defer absolutely to what is written or simply paraphrase parts of the text to support their positions; and they underestimate dramatically the reading difficulties they actually face. Most tragic and frightening of all, increased science education does not help, as the same patterns are found among university undergraduate students who have taken substantial post-secondary science as among high school students with considerably less science education.

Simple View of Reading

We have argued that the results described above can be attributed to a simple view of reading that students hold (Norris and Phillips 2008). Reading can seem to be a simple process and text sometimes can seem transparent, especially for accomplished readers reading in areas in which their background knowledge is superior. Frequently in these latter contexts, reading appears automatic and little more than recognizing the words and locating information in the text. However, what might appear true of accomplished readers reading in their areas of expertise is not really true, and not at all true when readers are less accomplished or when accomplished readers are dealing with text outside their expertise. Unfortunately, what appears true about reading is the view that is implicit in many of the instructional and assessments tasks found in schools (Phillips et al. in press). Thus, in students' minds, the simple view engenders a belief that reading is being able to say the words correctly.

Science background doesn't help those with a simple view of reading because background knowledge matters only in the context of sound reading strategies (Phillips 1988). This fact explains why university students perform no better at interpreting science texts than high school students. They are unable to use their additional scientific knowledge because they hold the same impoverished view of reading as their younger counterparts.

As opposed to reading as word recognition and information location, we have argued that reading is best thought of as an inquiry process (Norris and Phillips 2008). The central idea of reading as inquiry is that reading is principled interpretation of text. Readers infer meaning from text by integrating relevant text information with their relevant background knowledge. Interpretation is about exploring meanings presupposed, implied, and reasonably justified by the text. Having knowledge about a topic prior to reading about it is useless to a reader who does not see the relevance of that knowledge by making inferential links between the knowledge and the text. Background knowledge is *made* relevant to an interpretation by forging inferential links between the knowledge and the text, highlighting reading as a constructive process.

Although it is constructive, reading is constrained in its possibilities. Completeness and consistency are the two main criteria for judging interpretations. Readers must ask which interpretation is more complete and more consistent. They are thus foreclosed from offering just any interpretation at all. Conceived in this manner, reading involves many of the same mental activities that are central to science, and, as demonstrated at the outset of this paper, encompasses a very large part of what is considered doing science. If science educators show little concern for text, see reading as merely a tool to get to science, they are likely to reinforce the attraction of the simple view of reading, and unwittingly underestimate the complexity and importance of reading in science.

Adapted Primary Literature

How, then, do we move the science curriculum and eventually science students away from the simple view of reading that has such deleterious consequences? To rephrase the premise with which we opened this paper, reading as inquiry could become part of the science curriculum with the assistance of adapted primary literature, conceived as literature that maintains the canonical form of scientific papers but is written so as to be understandable by school students (Baram-Tsabari and Yarden 2005; Falk et al. 2008). By design, adapted primary literature is more like the language of science than the language of traditional school science. As such, adapted primary literature can become the language of school science to the enormous benefit of students by helping to bridge the gap to the language of science.

References

Baram-Tsabari, A., & Yarden, A. (2005). Text genre as a factor in the formation of scientific literacy. *Journal of Research in Science Teaching*, *42*, 403–428.

Beamish, J., & Herman, T. (2003). Adsorption and desorption of helium in aerogels. *Physica B*, *329–333*, 340–341.

Ebbers, M., & Rowell, P. (2002). Description is not enough: Scaffolding children's explanations. *Primary Science Review*, *74*, 10–13.

Falk, H., Brill, G., & Yarden, A. (2008). Teaching a biotechnology curriculum based on adapted primary literature. *International Journal of Science Education*, *30*, 1841–1866.

Ford, D. J. (2005). Representations of science within children's trade books. *Journal of Research in Science Teaching*, *43*, 214–235.

Meldrum, A., Boatner, L. A., & Ewing, R. C. (2002). Nanocrystalline zirconia can be amorphized by ion radiation. *Physical Review Letters*, *88*, 025503–1–025503–4.

Myers, G. (1991). Lexical cohesion and specialized knowledge in science and popular science texts. *Discourse Processes*, *14*, 1–26.

Myers, G. (1992). Textbooks and the sociology of scientific knowledge. *English for Specific Purposes*, *11*, 3–17.

Myers, G. (1997). Words and pictures in a biology textbook. In T. Miller (Ed.), *Functional approaches to written text: Classroom applications* (pp. 93–104). Paris: USIA.

Newton, D. P., & Newton, L. D. (2000). Do teachers support causal understanding through their discourse when teaching primary science? *British Educational Research Journal*, *26*, 599–613.

Newton, L. D., Newton, D. P., Blake, A., & Brown, K. (2002). Do primary school science books for children show a concern for explanatory understanding? *Research in Science & Technological Education*, *20*, 227–240.

Norris, S. P. (1992). Practical reasoning in the production of scientific knowledge. In R. Duschl, & R. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 195–225). Albany, NY: State University of New York Press.

Norris, S. P., & Phillips, L. M. (1994). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching*, *31*, 947–967.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, *87*, 224–240.

Norris, S. P., & Phillips, L. M. (2008). Reading as inquiry. In R. A. Duschl, & R. E. Grandy (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 233–262). Rotterdam, The Netherlands: Sense.

Norris, S. P., Phillips, L. M., & Korpan, C. A. (2003). University students' interpretation of media reports of science and its relationship to background knowledge, interest, and reading difficulty. *Public Understanding of Science*, *12*, 123–145.

Penney, K., Norris, S. P., Phillips, L. M., & Clark, G. (2003). The anatomy of junior high school science textbooks: An analysis of textual characteristics and a comparison to media reports of science. *Canadian Journal of Science, Mathematics and Technology Education*, *3*, 415–436.

Phillips, L. M. (1988). Young readers' inference strategies in reading comprehension. *Cognition and Instruction*, *5*, 193–222.

Phillips, L. M., & Norris, S. P. (1999). Interpreting popular reports of science: What happens when the reader's world meets the world on paper? *International Journal of Science Education*, *21*, 317–327.

Phillips, L. M., Norris, S. P., Smith, M. L., Buker, J., & Kasper, C. (in press). Assessment techniques corresponding to scientific texts in commercial reading programs: Do they promote scientific Literacy? *Alberta Journal of Educational Research*.

Suppe, F. (1998). The structure of a scientific paper. *Philosophy of Science*, *65*, 381–405.

Tenopir, C., & King, D. W. (2004). *Communication patterns of engineers*. Hoboken, NY: Wiley.

Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. Buckingham, UK: Open University Press.

Wignell, P. (1987). '*In your own words*' *Writing Project Report 1987 (Working Papers in Linguistics 5)*. Sydney, Australia: Department of Linguistics, University of Sydney.

Yore, L. D., Craig, M. T., & Maguire, T. O. (1998). Index of science reading awareness: An interactive-constructive model, text verification, and grades 4–8 results. *Journal of Research in Science Teaching*, *35*, 27–51.