STEM Topic: Scientific literacy, reading and writing, comprehension and argument

Kalman, C.S. 2011. Enhancing students' conceptual understanding by engaging science text with reflective writing as a hermeneutical circle. Science and Education. Vol. 20, 159-172.

> Students can have great difficulty reading scientific texts and trying to cope with the professor in the classroom. Part of the reason for students' difficulties is that for a student taking a science gateway course the language, ontology and epistemology of science are akin to a foreign culture. There is thus an analogy between such a student and an anthropologist spending time among a native group in some remote part of the globe. This brings us naturally to the subject of hermeneutics. It is through language that we attempt to understand an alien culture. The hermeneutical circle involves the interplay between our construct of the unfamiliar with our own outlook that deepens with each pass. It can be argued that for novice students to acquire a full understanding of scientific texts, they also need to pursue a recurrent construction of their comprehension of scientific concepts. In this paper it is shown how an activity, reflective-writing, can enhance students' understanding of concepts in their textbook by getting students to approach text in the manner of a hermeneutical circle. This is illustrated using studies made at three postsecondary institutions.

Osborne, J.F., Patterson, A. 2011. Scientific argument and explanation: A necessary distinction? Science Education. Vol. 95, 627-638.

> In this paper, we argue that there is an emergent confusion in the literature in the use of the terms "argument" and "explanation." Drawing on a range of publications, we point to instances where these terms are either used inappropriately or conflated. We argue that the distinction between these two constructs is, however, important as a lack of clarity of fundamental concepts is problematic for a field. First, a lack of common conception hinders effective communication and, second, it makes defining the nature of the activity we might expect students to engage in more difficult. Drawing on a body of scholarship on argument and explanation, this paper is an attempt to clarify the distinction and to explain why such a distinction might matter.

Desaulniers Miller, M.C., Montplaisir, L.M., Offerdahl, E.G., Cheng, F.C., Ketterling, G.L. 2010. Comparison of views of the nature of science between natural science and nonscience majors. Life Sciences Education. Vol. 9, 45-54.

> Science educators have the common goal of helping students develop scientific literacy, including understanding of the nature of science (NOS). University faculties are challenged with the need to develop informed NOS views in several major student subpopulations, including science majors and nonscience majors. Research into NOS views of undergraduates, particularly science majors, has been limited. In this study, NOS views of undergraduates in introductory environmental science and upper-level animal behavior courses were measured using Likert items and open-ended prompts. Analysis revealed similarities in students' views between the two courses; both populations held a mix of naïve, transitional, and moderately informed views. Comparison of pre- and postcourse mean scores revealed significant changes in NOS views only in select aspects of NOS. Student scores on sections addressing six aspects of NOS were significantly different in most cases, showing notably uninformed views of the distinctions

between scientific theories and laws. Evidence-based insight into student NOS views can aid in reforming undergraduate science courses and will add to faculty and researcher understanding of the impressions of science held by undergraduates, helping educators improve scientific literacy in future scientists and diverse college graduates.

McDermott, M.A., Hand, B. 2010. A secondary reanalysis of student perceptions of non-traditional writing tasks over a ten year period. Journal of Research in Science Teaching. Vol. 47, 518-539.

This study aims to add to the growing research related to the implementation of non-traditional writing tasks in classrooms to encourage science literacy. A secondary reanalysis methodology was employed to review student interviews collected as a part of several individual studies during a ten year research program. This method established an interpretive framework different than the particular frameworks guiding the individual studies. In doing so, a greater ability to generalize findings was sought. Main assertions emerging from the student responses analyzed include recognition of benefits of non-traditional writing, recognition of the need for particular task characteristics to encourage these benefits, and recognition of greater cognitive activity than is present in typical science classroom writing.

Brickman, P., Gormally, C., Armstrong, N., Hallar, B. 2009. Effects of inquiry-based learning on students' science literacy skills and confidence. International Journal for the Scholarship of Teaching and Learning. Vol. 3, 22.

Calls for reform in university education have prompted a movement from teacher- to student-centered course design, and included developments such as peer-teaching, problem and inquiry-based learning. In the sciences, inquiry-based learning has been widely promoted to increase literacy and skill development, but there has been little comparison to more traditional curricula**.** In this study, we demonstrated greater improvements in students' science literacy and research skills using inquiry lab instruction. We also found that inquiry students gained self-confidence in scientific abilities, but traditional students' gain was greater –likely indicating that the traditional curriculum promoted over-confidence. Inquiry lab students valued more authentic science exposure but acknowledged that experiencing the complexity and frustrations faced by practicing scientists was challenging, and may explain the widespread reported student resistance to inquiry curricula.

Corner, A., Hahn, U. 2009. Evaluating science arguments: Evidence, uncertainty, and argument strength. Journal of Experimental Psychology: Applied. Vol. 15, 199-212.

Public debates about socioscientific issues are increasingly prevalent, but the public response to messages about, for example, climate change, does not always seem to match the seriousness of the problem identified by scientists. Is there anything unique about appeals based on scientific evidence—do people evaluate science and nonscience arguments differently? In an attempt to apply a systematic framework to people's evaluation of science arguments, the authors draw on the Bayesian approach to informal argumentation. The Bayesian approach permits questions about how people evaluate science arguments to be posed and comparisons to be made between the evaluation of science and nonscience arguments. In an experiment involving three separate argument evaluation tasks, the authors investigated whether people's evaluations of science and nonscience arguments differed in any meaningful way. Although some differences were observed in the relative strength of science and nonscience arguments,

the evaluation of science arguments was determined by the same factors as nonscience arguments. Our results suggest that science communicators wishing to construct a successful appeal can make use of the Bayesian framework to distinguish strong and weak arguments.

Glynn, S.M., Taasoobshirzai, G., Brickman, P. 2009. Science motivation questionnaire: Construct validation with nonscience majors. Journal of Research in Science Teaching. Vol. 46, 127-146.

This study examined how 770 nonscience majors, enrolled in a core-curriculum science course, conceptualized their motivation to learn science. The students responded to the Science Motivation Questionnaire, a 30- item Likert-type instrument designed to provide science education researchers and science instructors with information about students' motivation to learn science. The students' scores on the Science Motivation Questionnaire were reliable and related to students' high school preparation in science, GPA in college science courses, and belief in the relevance of science to their careers. An exploratory factor analysis provided evidence of construct validity, revealing that the students conceptualized their motivation to learn science in terms of five dimensions: intrinsic motivation and personal relevance, self-efficacy and assessment anxiety, self-determination, career motivation, and grade motivation. Women and men had different profiles on these dimensions, but equivalent overall motivation to learn science. Essays by all of the students explaining their motivation to learn science and interviews with a sample of the students were used to interpret Science Motivation Questionnaire scores. The findings were viewed in terms of a social-cognitive theory of learning, and directions for future research were discussed.

Kalman, C. 2009. The need to emphasize epistemology in teaching and research. Sci & Educ. Vol 18, 325-347.

The views on epistemology by philosophers of science are developed through an historical lens. Enabling students to develop a scientific mindset is complicated by student's views on the Nature of Science. Students need to appreciate the history of science and to contrast different frameworks. In order to do this, students have to be able to follow presentations in class and read their textbooks. Although individual words are understandable, the sentences appear to take the form of an unknown language. The solution utilized in this paper is to get students to approach their reading of their textbooks in the manner of the hermeneutical circle through an activity called Reflective Writing.

Lucas, A., 2009. Using peer instruction and I-clickers to enhance student participation in calculus. PRIMUS. Vol. 19, 219-231.

In my Calculus classes I encourage my students to actively reflect on course material, to work collaboratively, and to generate diverse solutions to questions. To facilitate this I use peer instruction (PI), a structured questioning process, and i-clickers, a radio frequency classroom response system enabling students to vote anonymously. This article concludes that PI and i-clickers enhance student participation and comprehension. It is important, however, that students write down their reasoning during PI so as not to be led astray by dominant group members

Armstrong, N.A., Wallace, C.S., Chang, S.M. 2008. Learning from writing in college biology. Res Sci Educ. Vol. 38, 483-499.

> This study used both quantitative and qualitative analyses to examine the influence of written arguments on learning in a college level introductory biology class and the types of metacognition employed by students while writing. Comparison of a treatment and control group indicates that the writing assignments used had minimal impact on overall content learning as measured by conventional exams. Subsequent interviews and think-aloud protocols with a subset of students indicated that writing arguments had the potential to foster learning through forward and backward search strategies. However, few of the students took advantage of this opportunity to use metacognitive skills. This study suggests that preparing written arguments is not sufficient, by itself, to have a reliable effect on student learning and is consistent with the view that students must be explicitly taught when and how to use different metacognitive strategies.

Gunersel, A.B., Simpson, N.J., Aufderheide, K.J., Wang, L. 2008. Effectiveness of calibrated peer review for improving writing and critical thinking skills in biology undergraduate students. J of the scholarship of Teaching and Learning, Vol. 8, 25-37.

> This study focuses on student development with Calibrated Peer Review (CPR) TM, a web-based tool created to promote writing and critical thinking skills. Research questions focus on whether or not students showed improvement in writing and reviewing competency with repeated use of CPR in a senior-level biology course and whether the difference between higher performing and lower performing students decreased over time. Four repeated measures analyses were conducted with different sets of students. Repeated measures analyses indicate that students showed improvement in writing skills and reviewer competency with repeated use of CPR. The difference between higher and lower performing students decreased over time in both writing skills and reviewer competency.

Martin-Hansen, L.M. 2008. First-year college students' conflict with religion and science. Science and Education. Vol. 17, 317-357.

> This study took place during a First Year Seminar course where 20 incoming college freshmen studied the central topic of the nature of science within the context of biological evolution. The instructor researched students' understandings in the nature of science as they progressed through the course by examining a variety of qualitative and quantitative data including class writings, pre- and post-test selected items from the VOSTS (Views on Science- Technology-Society), and interviews. The intended outcomes of the course were to reduce the number of student misconceptions in the nature of science and to ease student apprehension when learning about evolution. Data were analyzed to determine whether students were moving toward a more generally accepted idea of the nature of science or toward another type of misconception.

Sampson, V., Clark, D.B. 2008. Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future direction. Published online 13 March, 2008, in Wiley InterScience (HYPERLINK "http://www.interscience.wiley.com" www.interscience.wiley.com).

Theoretical and empirical research on argument and argumentation in science education has intensified over the last two decades. The term “argument” in this review refers to the artifacts that a student or a group of students create when asked to articulate and justify claims or explanations whereas the term “argumentation” refers to the process of constructing these artifacts. The intent of this review is to provide an overview of several analytic frameworks that science educators use to assess and characterize the nature of or quality of scientific arguments in terms of three focal issues: structure, justification, and content. To highlight the foci, affordances, and constraints of these different analytic methods, the review of each framework includes an analysis of a sample argument. The review concludes with a synthesis of the three focal issues and outlines several recommendations for future work. Ultimately, this examination and synthesis of these frameworks in terms of how each conceptualizes argument structure, justification, and content is intended.

Carlson, C.A. 2007. A simple approach to improving student writing: An example from hydrology. J. of College Science Teaching. 48-54.

Using the simple approach described in this article, college science instructors can help students become independent thinkers and writers in science. The unique character of this approach is that it shows students how to formulate the questions they need to answer in their writing, as well as how to answer them. Rather than using a cookbook approach, role modeling teaches students that writing is a process and helps them to engage the science.

Caldwell, J.E. 2007. Clickers in the large classroom: Current research and best-practice tips. Live Science Education. Vol. 6, 9-21.

Audience response systems (ARS) or clickers, as they are commonly called, offer a management tool for engaging students in the large classroom. Basic elements of the technology are discussed. These systems have been used in a variety of fields and at all levels of education. Typical goals of RS questions are discussed, as well as methods of compensating for the reduction in lecture time that typically results from their use. Examples of ARS use occur throughout the literature and often detail positive attitudes from both students and instructors, although exceptions do exist. When used in classes, ARS clickers typically have either a benign or positive effect on student performance on exams, depending on the method and extent of their use, and create a more positive and active atmosphere in the large classroom. These systems are especially valuable as a means of introducing and monitoring peer learning methods in the large lecture classroom. So that the reader may use clickers effectively in his or her own classroom, a set of guidelines for writing good questions and a list of best-practice tips have been culled from the literature and experienced users.

Duit, R. 2007. Science education research internationally: Conceptions, research methods, domains of research. Eurasia Journal of Mathematics, Science & Technology Education. Vol. 3, 3-15.

Disappointing results of international monitoring studies such as TIMSS (Third International Mathematics and Science Study) and PISA (Programme for International Student Assessment) have fuelled another general debate on the need for a sufficient level of scientific literacy and the necessity to improve the quality of science instruction in school. Science education research has played essential roles not only in analyzing the actual state of scientific literacy and the actual practice in schools but also in improving instructional practice and teacher education. A conception of science education research that is relevant for improving school practice and teacher education programs will be presented here. This conception is based on a Model of Educational Reconstruction which holds that science subject matter issues and students' learning needs and capabilities have to be given equal attention in quality development attempts. Further, research and development activities have to be intimately linked. It is argued that science education research drawing on this framework is an indispensable prerequisite for improving instructional practice and hence for the further advancement of scientific literacy.

Nelson, C.E. 2007. Teaching evolution effectively: A central dilemma and alternative strategies. McGill Journal of Education. Vol. 42, 265-285.

We will continue to have a public that is scientifically illiterate until we find ways to get faculty in post-secondary science classes to use effective pedagogical approaches. In this article, I present three scientifically and pedagogically valid strategies for helping students evaluate their initial understandings of evolution and to compare those understandings with more scientifically valid formulations. Adoption of such strategies in post-secondary teaching is central to more adequate preparation of future scientists, opinion leaders, and secondary school teachers.

Quitadamo, I.J., Kurtz, M.J. 2007. Learning to improve: Using writing to increase critical thinking performance in general education biology. Life Sciences Education. Vol. 6, 140-154.

Increasingly, national stakeholders express concern that U.S. college graduates cannot adequately solve problems and think critically. As a set of cognitive abilities, critical thinking skills provide students with tangible academic, personal, and professional benefits that may ultimately address these concerns. As an instructional method, writing has long been perceived as a way to improve critical thinking. In the current study, the researchers compared critical thinking performance of students who experienced a laboratory writing treatment with those who experienced traditional quiz-based laboratory in a general education biology course. The effects of writing were determined within the context of multiple covariables. Results indicated that the writing group significantly improved critical thinking skills whereas the nonwriting group did not. Specifically, analysis and inference skills increased significantly in the writing group but not the nonwriting group. Writing students also showed greater gains in evaluation skills; however, these were not significant. In addition to writing, prior critical thinking skill and instructor significantly affected critical thinking performance, whereas other covariables such as gender, ethnicity, and age were not significant. With improved critical thinking skill, general education biology students will be better prepared to solve problems as engaged and productive citizens.

Wieman, C. 2007. Why not try. A scientific approach to science education. Change. September/October. 9-16.

The purpose of science education is no longer simply to train that tiny fraction of the population who will become the next generation of scientists. We need a more scientifically literate populace to address the global challenges that humanity now faces and that only science can explain and possibly mitigate, such as global warming, as well as to make wise decisions, informed by scientific understanding, about issues such as genetic modification. Moreover, the modern economy is largely based on science and technology, and for that economy to thrive and for individuals within it to be successful; we need technically literate citizens with complex problem-solving skills.

In short, we now need to make science education effective and relevant for a large and necessarily more diverse fraction of the population. What do I mean by an effective education in science? I believe a successful science education transforms how students think, so that they can understand and use science like scientists do. (See Figure 1). But is this kind of transformation really possible for a large fraction of the total population?

Best, R.M., Rowe, M., Ozuru, Y., McNamara, D.S. 2005. Deep-level comprehension of science texts. The role of the reader and the text. Top Lang Disorders. Vol. 25, 65-83.

Many students from elementary school through college encounter difficulty understanding their science textbooks, regardless of whether they have language disorders. This article discusses some of the particular difficulties associated with science text comprehension and possible remedies for facilitating and enhancing comprehension of challenging expository text materials. Specifically, the authors focus on the difficulties associated with generating inferences needed to comprehend science texts. The successful generation of inferences is affected by factors such as students' prior knowledge and reading strategies, and the manner in which science texts are written. Many students lack the necessary prior knowledge and reading strategies to generate inferences and thus comprehend science texts only poorly. Further, science texts are typically "low-cohesion" texts, which means that they require readers to generate many inferences and fill in conceptual gaps. Remedies for overcoming comprehension difficulties include matching texts to students' knowledge level and providing explicit instruction aimed at teaching students to use reading comprehension strategies for comprehension monitoring, paraphrasing, and elaborations. The computer-supported tool iSTART (Interactive Strategy Training for Active Reading and Thinking) is introduced as a technological support to assist students and teachers in the teaching/learning enterprise.

Ramaley, J.A., Olds, B.M., Earle, J. 2005. Becoming a learning organization: New directions in science education research at the National Science Foundation. Journal of Science Education and Technology. Vol. 14, 173-190.

The Education and Human Resources (EHR) Directorate at the National Science Foundation has been examining its role in supporting the development of new approaches to science, technology, engineering and mathematics (STEM) education. This article explores what it means to be scientifically literate, what it takes to become a learning organization, how the EHR Directorate is working towards becoming such an organization through rigorous selfstudy, and how EHR can best manage its large portfolio of awards that support investigations in STEM education to enhance their collective value to researchers, policymakers and educators. Several elements of the self-study process are described, and the implications for the Directorate as well as for the field of researchers in science education are explored.

Schwartz, R.S., Lederman, N.G., Crawford, B.A. 2004. Developing views of Nature of Science in an authentic context: An explicit approach to bridging the gap between Nature of Science and scientific inquiry. Wiley Periodicals, Inc. Science Education. Vol. 88, 610-645.

> Reform efforts emphasize teaching science to promote contemporary views of the nature of science (NOS) and scientific inquiry. Within the framework of situated cognition, the assertion is that engagement in inquiry activities similar to those of scientists provides a learning context conducive to developing knowledge about the methods and activities through which science progresses, and, in turn, to developing desired views of NOS. The inclusion of a scientific inquiry context to teach about NOS has intuitive appeal. Yet, whether the learners are students, teachers, or scientists, the empirical research does *not* generally support the claim that engaging in scientific inquiry alone enhances conceptions of NOS. We studied developments in NOS conceptions during a science research internship course for preservice secondary science teachers. In addition to the research component, the course included seminars and journal assignments. Interns' NOS views were assessed in a pre/post format using the Views of Nature of Science questionnaire, [VNOS-C] and interviews. Results indicate most interns showed substantial developments in NOS knowledge. Three factors were identified as important for NOS developments during the internship: (1) reflection, (2) context, and (3) perspective. Reflective journal writing and seminars had the greatest impact on NOS views. The science research component provided a context for reflection. The interns' role perspective appeared to impact their abilities to effectively reflect. Interns who assumed a reflective stance were more successful in deepening their NOS conceptions. Those who maintained a scientist's identity were less successful in advancing their NOS views through reflection. In light of these results, we discuss the significance and challenges to teaching about NOS within inquiry contexts.

Duit, R., Treagust, D.F. 2003. Conceptual change: A powerful framework for improving science teaching and learning. International Journal of Science Education. Vol. 25, 671-688.

> In this review, we discuss (1) how the notion of conceptual change has developed over the past three decades, (2) giving rise to alternative approaches for analysing conceptual change, (3) leading towards a multiperspective view of science learning and instruction that (4) can be used to examine scientific literacy and (5) lead to a powerful framework for improving science teaching and learning.

Kelly, G.J., Bazerman, C. 2003. How students argue scientific claims: A rhetorical-semantic analysis. Applied Linguistics. Vol. 24, 28-55.

> This paper investigates ways students engage in scientific reasoning practices through the formulation of written argument. Through textual analysis of university students' scientific writing we examined how general theoretical claims are tied to specific data in constructing evidence. The student writers attended a writing-intensive university oceanography course that required them to write a technical paper drawing from multiple interactive geological data sets concerning plate tectonics. Two papers, chosen as exemplary by the course instructor, were analysed in three ways: First, genre analysis was applied to identify the rhetorical moves used by the authors to complete the academic task. Second, a previously developed model of epistemic generality was used to uncover the relationships of theoretical assertions and empirical data. Third, an analysis of lexical cohesion mapped the recurrence and relationships of topics throughout the student papers. These analyses identified ways that the students engaged with

the genre (as defined within the activity system of the course): the successful student authors were shown to adjust the epistemic level of their claims to accomplish different rhetorical goals, build theoretical arguments upon site specific data, method, introduce key concepts that served as anchors for subsequent conceptual development, and tie multiple strands of empirical data to central constructs through aggregating sentences. Educational applications are discussed.

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 Science. Vol. 12, 123-145.

> Three hundred and eight first and second year university students were asked to read five media reports that described recent scientific research and findings. We instructed the students to interpret and make judgments about the certainty, status, and role of statements identified in the reports, and to assess how much knowledge they had about the general topics of the reports, their interest in the general topics, and their difficulty reading each report. Students' performance on the interpretive tasks mirrored in major detail the performance of a group of high school students studied previously. The university students displayed a certainty bias in their responses to questions regarding truth status, confused cause and correlation, and had difficulty distinguishing explanations of phenomena from the phenomena themselves. The university students' self-assessments of their knowledge, interests, and reading difficulty were able to explain virtually none of the variance in their interpretive performance. In general, the university students had an inflated view of their ability to understand the five media reports. Implications for the development of scientific literacy are discussed.

Roth, W.M., Lee, S. 2002. Scientific literacy as a collective praxis. Public Understanding Science. Vol. 11, 33-56.

> In this article, we conceive of scientific literacy as a property of collective activity rather than individual minds. We think of knowing and learning science as situated in and distributed across social and material aspects of a setting. To support the proposed conception, we provide several detailed cases from our three-year multi-site ethnographic study of science in one community, featuring different types of citizens who walk a creek, interact during an environment-oriented open-house event, discuss water problems, collect data, and have different conceptions of human-environment relations. The case studies show that collectively, much more advanced forms of scientific literacy are produced than any individual including scientists could produce. Creating opportunities for scientific literacy to emerge from collective activity, irrespective of whether one or more participants know some basic scientific facts, presents challenges to science educators very different from teaching basic facts and skills to individuals.

Taconis, R., Ferguson-Hessler, M.G.M., Broekkamp, H. 2001. Teaching science problem solving: An overview of experimental work. Journal of Research in Science Teaching. Vol. 38, 442-468.

> The traditional approach to teaching science problem solving is having the students work individually on a large number of problems. This approach has long been overtaken by research suggesting and testing other methods, which are expected to be more effective. To get an overview of the characteristics of good and innovative problem-solving teaching strategies, we performed an analysis of a number of articles published between 1985 and 1995 in high-

standard international journals, describing experimental research into the effectiveness of a wide variety of teaching strategies for science problem solving. To characterize the teaching strategies found, we used a model of the capacities needed for effective science problem solving, composed of a knowledge base and a skills base. The relations between the cognitive capacities required by the experimental or control treatments and those of the model were specified and used as independent variables. Other independent variables were learning conditions such as feedback and group work. As a dependent variable we used standardized learning effects. We identified 22 articles describing 40 experiments that met the standards we deemed necessary for a meta-analysis. These experiments were analyzed both with quantitative (correlational) methods and with a systematic qualitative method. A few of the independent variables were found to characterize effective strategies for teaching science problem solving. Effective treatments all gave attention to the structure and function (the schemata) of the knowledge base, whereas attention to knowledge of strategy and the practice of problem solving turned out to have little effect. As for learning conditions, both providing the learners with guidelines and criteria they can use in judging their own problem-solving process and products, and providing immediate feedback to them were found to be important prerequisites for the acquisition of problem-solving skills. Group work did not lead to positive effects unless combined with other variables, such as guidelines and feedback.

Brickhouse, N.W., Dagher, Z.R., Letts, W.J., Shipman, H.L. 2000. Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. Journal of Research in Science Teaching. Vol. 37, 340-362.

Arguments for teaching about the nature of science have been made for several decades. The most recent science education policy documents continue to assert the need for students to understand the nature of science. However, little research actually explores how students develop these understandings in the context of a specific course. We examine the growth in students' understanding about the nature of astronomy in a one-semester college course. In addition to student work collected for 340 students in the course, we also interviewed focus students three times during the course. In this article we briefly describe class data and discuss in detail how five students developed their ideas throughout the course. In particular, we show the ways in which students respond to instruction with respect to the extent to which they (a) demand and examine evidence used for justifying claims, (b) integrate scientific and religious views, and (c) distinguish between scientific and nonscientific theories.

Musheno, B.V., Lawson, A.E. 1999. Effects of learning cycle and traditional text on compreshension of science concepts by students at differing reasoning levels. Journal of Research in Science Teaching. Vol. 36, 23-37.

Research has found the learning cycle to be effective for science instruction in hands-on laboratories and interactive discussions. Can the learning cycle, in which examples precede the introduction of new terms, also be applied effectively to science text? A total of 123 high school students from two suburban schools were tested for reasoning ability, then randomly assigned to read either a learning cycle or traditional text passage. Immediate and delayed posttests provided concept comprehension scores that were analyzed by type of text passage and by reasoning level. Students who read the learning cycle passage earned higher scores on concept comprehension questions than those who read the traditional passage, at all reasoning levels. This result supports the hypothesis that reading comprehension and scientific inquiry involve similar information-processing strategies and confirms the prediction that science text presented in the learning cycle format is more comprehensible for readers at all reasoning levels.

Abd-El-Khalick, F., Bell, R.L., Lederman, N.G. 1998. The nature of science and instructional practice: Making the unnatural natural. John Wiley & Sons, Inc. Science Education. Vol. 82, 417-436.

The purpose of this study was to delineate the factors that mediate the translation of preservice teachers' conceptions of the nature of science (NOS) into instructional planning and classroom practice. Fourteen preservice secondary science teachers participated in the study. Prior to their student teaching, participants responded to an open-ended questionnaire designed to assess their conceptions of the NOS. Analysis of the questionnaires was postponed until after the completion of student teaching to avoid biasing the collection and/or analysis of other data sources. Throughout student teaching, participants' daily lesson plans, classroom videotapes, and portfolios, and supervisors' weekly clinical observation notes were collated. These data were searched for explicit references to the NOS. Following student teaching, participants were individually interviewed to validate their responses to the open-ended questionnaire and to identify the factors or constraints that mediate the translation of their conceptions of the NOS into their classroom teaching. Participants were found to possess adequate understandings of several important aspects of the NOS including the empirical and tentative nature of science, the distinction between observation and inference, and the role of subjectivity and creativity in science. Many claimed to have taught the NOS through science-based activities. However, data analyses revealed that explicit references to the NOS were rare in their planning and instruction. Participants articulated several factors for this lack of attention to the NOS. These included viewing the NOS as less significant than other instructional outcomes, preoccupation with classroom management and routine chores, discomfort with their own understandings of the NOS, the lack of resources and experience for teaching the NOS, cooperating teachers' imposed restraints, and the lack of planning time. In addition to these volunteered constraints, the data revealed others related to an intricate interaction between participants' perspectives on the NOS, pedagogy, and instructional outcomes.

McComas, W.F. 1998. The principle elements of the Nature of Science: dispelling the myths. *Adapted from the chapter in W. F. McComas (ed.) The Nature of Science in Science Education*, 53-70. © 1998 Kluwer Academic Publishers, Netherlands

The "myths of science" discussed here are commonly included in science textbooks, in classroom discourse and in the minds of adult Americans. These fifteen issues, described here as "myths of science," do not represent all of the important issues that teachers should consider when designing instruction relative to the nature of science, but may serve as starting points for evaluating current instructional foci while enhancing future curriculum design. Misconceptions about science are most likely due to the lack of philosophy of science content in teacher education programs and the failure of such programs to provide real science research experiences for preservice teachers while another source of the problem may be the generally shallow treatment of the nature of science in the textbooks to which teachers might turn for guidance. Some of these myths, such as the idea that there is a scientific method, are most likely caused by the explicit inclusion of faulty ideas in textbooks while others, such as lack of knowledge of the social construction of scientific knowledge, are the result of omissions in texts.

Johnstone, A.H. 1991. Why is science difficult to learn? Things are seldom what they seem. Journal of Computer Assisted Learning. Vol. 7, 75-83

The difficulties of learning science are related to the nature of science itself and to the methods by which science is customarily taught without regard to what is known about children's learning. An information processing model is proposed to guide thinking and research in this area.