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Adapted Primary Literature

The Use of Authentic Scientific Texts in Secondary Schools

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This book is dedicated to Stephen Norris, his memory, his legacy, and his family and friends.

When we three (Anat, Steve and Linda) agreed to work together in 2010 it was an exciting time for us. We bubbled with ideas and looked forward very much to taking on this book. We planned and met at meetings, talked over breakfasts and dinners and skyped numerous times to clarify our thoughts and polish our wording.

On February 18, 2014, all of that changed with Steve's sudden and untimely passing. Steve is well known internationally for his leading work on reading scientific texts, scientific literacy, scientific knowledge and reasoning, the public understanding of science as well as his work on test validation and critical thinking. He has an outstanding research and publication record with numerous high quality publications in the form of books, peer-reviewed articles, and chapters. His work has been funded by the Social Sciences and Humanities Research Council of Canada for the duration of his academic career. He was a Tier 1 Canada

Research Chair in Scientific Literacy and the Public Understanding of Science, notably he was the sole scholar in Canada awarded a research chair in the field of science education. Within Canada he was a national leader for the five centers for research in youth, science teaching and learning funded by the Natural Sciences and Engineering Research Council of Canada. Steve's work is used internationally and he has given willingly of his time and expertise.

Jonathan Osbourne, a colleague and friend, said it well: At his heart, Steve Norris was what all communities need—a critical friend. Watching a presentation by him was to observe a model of clarity both in the deliberate thoughtful manner it was presented and in the depth of thought that had gone into his arguments and questions. He was somebody who recognized that the first duty of an intelligent man is to state the obvious and to ask the hard questions that others had avoided. In doing so, he enriched our community and advanced our thinking. He was also an individual of great wit and charm who took profound interest in helping and supporting all. He passed away doing what he loved, outdoors snowshoeing with his wife and friends. For him it was swift. For those of us who knew him it is another rent in the fabric of life. For our science community it is a great loss.

Steve was engaged completely with the writing of this book with his two friends and colleagues at the time of his death. He had the path clearly specified and we took up the challenge and continued to complete this book without his thoughtful and helpful

comments. We trust that we have served him well. He saw innovative possibilities for the use and adoption of adapted primary literature (APL) and was striving to advance the idea in various academic platforms, including the writing of this book. We hope this book will enable others to realize Steve's vision and grasp the APL idea for promoting science education through the reading of authentic scientific texts.
We are indeed blessed to have known Steve and doubly blessed to have worked and walked many paths with him.

Anat Yarden and Linda Phillips

Stephen P. Norris
1949–2014

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About the Authors

Dr. Stephen P. Norris* was Professor and Canada Research Chair in Scientific Literacy and the Public Understanding of Science at the University of Alberta, Canada. He has undergraduate degrees in Physics and in Science Education, a master's degree in Science Education, and a Ph.D. in the Philosophy of Education. He has published extensively in philosophy of education and science education for over three decades. Steve has a longstanding and international reputation for his work on reading scientific texts, scientific literacy, scientific knowledge and reasoning, as well as the public understanding of science as well as his work on testing and critical thinking. During the last 20 years he has published extensively on interpreting scientific text. His most recent books are: a co-authored volume with Linda Phillips and John Macnab, *Visualization in Mathematics, Reading and Science Education* published by Springer; and an edited volume, *Reading for Evidence and Interpreting Visualizations in Mathematics and Science Education*, published by Sense.

Dr. Linda M. Phillips is Centennial Professor and Director of the Canadian Centre for Research on Literacy at the University of Alberta. She holds two undergraduate degrees and a master's from Memorial University of Newfoundland and a Ph.D. in Cognition and Reading from the University of Alberta. She is the recipient of national and international awards for outstanding research, teaching, and service. She has served on several editorial boards including *Reading Research Quarterly*; and was the senior editor for the *Handbook of Language and Literacy Development: A Roadmap from 0 to 60 Months*. Linda has published numerous books, chapters and articles in top tier language and literacy venues. Her current research includes: the development of a *Test of Early Language and Literacy (TELL)* for children ages 3–8 years; the study of children's reasoning when reading

*Author was deceased at the time of publication.

in conventional and dynamic assessment contexts; the exploration of scientific literacy (reading when the content is science); the study of emergent and family literacy; and, the use of fMRI studies in understanding reading development.

Dr. Anat Yarden is Associate Professor and the Head of the Biology Group at the Department of Science Teaching at the Weizmann Institute of Science, Israel. She holds an undergraduate degree in Agricultural Sciences (The Hebrew University of Jerusalem), a master's degree and a Ph.D. in Molecular Biology (Weizmann Institute of Science), and has postdoctoral training in Genetics (Stanford University). The primary theme in all of her academic activities has been the attempt to adapt practices employed by scientists, to the processes by which students and teachers accumulate and advance their knowledge within the discipline of biology. Towards this end, her group pioneered the adaption of primary scientific literature for the teaching and learning of biology in high schools. She is the recipient of a number of prestigious fellowships and awards, including the Fridenberg Foundation Award of the Israel Academy of Sciences and Humanities. She published extensively in leading peer-reviewed journals, is a member of the editorial board of several leading journals in science education, and serves as an associate editor for the Journal of Research in Science Teaching (JRST). She has played active roles in the academic functions of the European Researchers in Didactics of Biology (ERIDOB) and the National Association of Research in Science Teaching (NARST) organizations.

Chapter 1
Prologue: The Origins of the First Adapted Primary Literature

> Papers by scientists reporting scientific research have two major advantages as materials for the teaching of science as enquiry. One advantage is obvious. They afford the most authentic, unretouched specimens of enquiry that we can obtain. . .The second advantage of original papers consists in the richness and relevance of the problems they pose for enquiry into enquiry. (Schwab 1962, p. 73)

The above quotation from Joseph Schwab invites us, reading him 50 years later, to notice scientific inquiry in a different place. We usually are encouraged to find scientific inquiry in the manipulative activities scientists engage to understand the natural world (e.g., National Research Council 2012, p. 24). Schwab tells us we can find inquiry in scientific papers. Indeed, he says those papers are "the most authentic, untouched specimens of inquiry." It is our belief that we can indeed find inquiry in scientific papers, and in reading and the writing of them that underlies and motivates this volume. To think that such papers are the most authentic examples of scientific inquiry truly is an intriguing thought that we ask you to explore with us throughout this book. This book is about what and how scientists read and write and what those practices imply for school science education.

Scientists usually report their research in articles that are published in professional journals. Since the scientists who did the research are also the ones describing it in the articles, such text is termed "primary literature" (Bazerman 1988; Goldman and Bisanz 2002). Primary literature is the way scientists communicate and the way they describe their research and findings. Thus, reading and writing scientific texts are common practices carried out by scientists as part of their scientific research accounting for about 50 % of their working time, and even more for the most productive scientists (Norris and Phillips 2008; Tenopir et al. 2003). Therefore, those practices should play an integral role in the teaching and learning of science alongside other scientific practices such as observing and measuring that already find a central role in science teaching and learning.

At the university and college level, courses that are accompanied by, or even based on reading primary literature, are quite common (Epstein 1970;

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Hoskins et al. 2007; Kozeracki et al. 2006). In addition to the possibility to expose these students to contemporary scientific discoveries, the use of primary literature for science learning can also support the development of scientific literacy. Using primary literature for teaching holds the possibility to acquaint students with the rationales for research plans, expose students to research methods and to discussions of their suitability to research questions, acquaint students with the language and structure of scientific communication, develop in students the ability to assess critically the goals and conclusions of scientific research, familiarize students with problems in certain disciplines, and demonstrate the continuity of the scientific research process (Yarden et al. 2001). Thus, teaching with primary literature exposes students to authentic inquiry practices of scientists, as suggested by Norris and Phillips (2008).

Can primary literature also be a way to learn science in high-schools? Learning through primary literature is difficult if not impossible for novices. Yet, Schwab (1962, p. 81) suggested more than 50 years ago that scientific articles "can be edited, excerpted and 'translated'" in order to enable their use for inquiry teaching and learning in high-school. We have taken up this challenge, and developed means to adapt primary literature articles to the knowledge level of high-school students and have termed this educational text genre Adapted Primary Literature (APL, Falk et al. 2008). The adaptation process maintains the canonical structure of the research article as well as its genre, while adapting its contents to the high-school students' prior knowledge level and cognitive abilities (Yarden et al. 2001). We provide several examples of APL articles in part III of the book and in the appendices.

There already exists various means to adapt scientific information to the knowledge level of a target audience. For example, articles in popular scientific magazines (such as Scientific American); science news briefs in daily newspapers (also Journalistic Reported Versions, JRV); popular science programs broadcasted on the public television (like Brainiac); and, perhaps the most ubiquitous of all, textbooks. Each of these communication forms present science in a manner that is very different from the way science is practiced and communicated among scientists. The discourse of science includes not only precise language but also particular ways in which language is used, conclusions are made, ideas are put together, explanations are constructed, and arguments are presented (Krajcik and Sutherland 2010). It thus can come as a surprise to notice that those features usually are absent from the texts and other forms of communication used to relate science to the non-scientific public and particularly to science students in schools.

It is unquestionable that learning to read and write clear and concise expository text, as in summaries of investigations in science class, is an essential preparation for many tasks outside of school (Alberts 2010); and that fundamental literacy practices such as reading, writing and oral discourse are essential to developing scientific literacy (Krajcik and Sutherland 2010). However, school students and educated individuals beyond the school age are known to have difficulties interpreting journalistic reported forms of science as mentioned above (Norris and Phillips 1994; Norris et al. 2003; Phillips and Norris 1999). As well, students in school have problems reading with comprehension scientific textbooks

(Snow 2010). Yet, these various ways of adapting primary scientific literature are meant to assist readers who are not scientists. Our conjecture for explaining this mismatch of intention and outcome is that these various forms of adaptation are insufficiently attuned to the language of science to be able to communicate science in a meaningful way.

By way of contrast, the adapted primary literature genre offers high school students and other non-scientists an opportunity to be exposed to the language of science as it is communicated by scientists. Adapted primary literature exhibits a reduced emphasis on language as a means of transmitting information and an elevated emphasis on language as an interpretive system of sense-making as articulated by Sutton (1998). Intuitively, exposing students to scientific language closer to the way it is used by scientists will present the students with overwhelming difficulties and not provide a solution to difficulties they have reading science. As this book unfolds our joint attempts to realize a vision for the APL genre will be seen to challenge this intuition. The language of science is not the problem. Rather, it is the language that distorts science and exists in tension with science that is problematic.

How the APL Idea Was Initiated

> It is more important that high school students understand how developmental biologists think, than they will be exposed to the wealth of information currently available in the field. (Benny Geiger, personal communication to Anat Yarden, 1996)

At the beginning of 1996, while Anat Yarden was completely immersed in studying the molecular mechanisms involved in cell growth arrest during zebra fish embryonic development, her academic interests took a sharp turn during a meeting with Benny Geiger (Prof. Benjamin Geiger, Department of Molecular Cell Biology, Weizmann Institute of Science). Benny, who served as the Dean of the Feinberg Graduate School at that time, was telling her about plans in the Department of Science Teaching to write a textbook in developmental biology for high school students who chose to major in biology for their matriculation examination (11th and 12th graders). As a scientist in the developmental biology field, Anat thought it would be impossible to cover the basics of the field in the 30 h that were devoted to it as an elective topic in the syllabus. Comprehending those basics requires knowledge of numerous concepts that usually are not familiar to high school students, and she thought that those concepts probably cannot be acquired in the allotted time.

The above quotation from that conversation changed Anat's thoughts about this idea, and actually overturned the way she conceived that biology can be taught and learned. Benny's thoughts are at the basis of our claim above that the language of science is not the problem with students' reading. Benny offered an intriguing suggestion to create a textbook in developmental biology out of scientific papers, in a manner similar to how an issue of a scientific journal, such as Development, is built. The rationale behind this idea was that learning using scientific articles may enable students to acquire knowledge about how scientists conduct their research in the field—the ways they plan their experiments, how they develop their justifications for conducting certain experiments, the means they use to present and discuss the results in the field—while avoiding the emphasis on systematic knowledge acquisition commonly found in developmental biology courses. Since it was clear that high school students are not able to read scientific papers, the proposal was made to adapt to the knowledge level of high school biology majors. These ideas implanted the first seeds of the APL genre, and subsequently led Anat to completely switch fields from a developmental biologist to a researcher in the science education field.

How the APL Idea Was Initially Realized

One of the initial challenges Anat Yarden and her colleague Gilat Brill faced when they started to develop the APL idea was to choose suitable papers for an APL-based curriculum aimed for novices in the field. They approached ten leading developmental biologists and asked them to name breakthrough papers in the field. The rationale was that learning through breakthrough papers might enable high school students to grasp major lines of thinking in developmental biology. At the time, they naively planned to include ten of the resulting papers in the textbook.

At those initial stages of the development of the APL idea, they thought to base an APL paper on data collected from several papers put together in a research paper format especially for an APL-based curriculum. There was even the possibility to carry out experiments and collect data in case the original articles were not clear enough for high school students. The first curriculum in developmental biology included two such papers: (i) Cell migration in the developing embryo: Migration of nuclear crest cells, based on Le Douarin and Teiller (1974) and Le Douarin et al. (1975); and (ii) Regulating head development in the Drosophila embryo: The role of *bicoid* gene, based on Driever and Nusslein-Volhard (1988) and Nusslein-Volhard et al. (1987). The papers displayed a canonical structure of scientific research papers—Introduction, Methods, Results, Discussion (Swales 2001)—as well as the genre in which research papers are usually written—a strong personal voice (Sutton 1998), persuasive and convincing text with high level claims, and hedging (Swales 2001).

A fundamental contribution to the development of the APL idea was made by the Chief Supervisor of Biology Education in Israel at that time, Bruria Agrest. She offered valuable comments and suggestions to multiple revisions of the APL papers in order to adjust them to the knowledge level of high school students. She suggested also to include a very short and basic introduction to the topic. Since scientific articles are written for experts in the field, not all the prior knowledge that is required for comprehending the APL papers can be provided within the papers

Table 1.1 The structure of the first APL-based curriculum: The secrets of embryonic development: study through research (Yarden and Brill 1999)

Section	Description
Part I: Introduction	Basic processes in embryonic development
	Unity among developmental processes
	Fundamental questions in developmental biology
Part II: Collection of research articles	Cell migration in the developing embryo: Migration of nuclear crest cells
	Regulating head development in the Drosophila embryo: The role of *bicoid* gene
	Loss of skeletal muscles in newborn mice bearing a mutation in the *myogenin* gene
	The gene *hedgehog* mediates the polarizing activity in the limb buds

themselves. Such an introduction should help novices become familiar with basic concepts and processes that are required for learning.

The APL-based curriculum was starting to take shape: a brief introduction to the topic accompanied with several APL papers (Table 1.1). The question that remained was about the number of APL papers that can be included in such a curriculum. Eventually, a compromise was made on four papers, instead of the original ten, in order to meet teachers' and supervisors' recommendations on what can be expected from high school students in the 30 h that are allocated for this topic in the syllabus.

In contrast to the approach with the first two adaptations, the next two APL papers were each adapted from a single primary literature paper. Those APL papers were purposely adapted to follow the original paper's logic and use its methodological approach and data. The two papers that were adapted in this manner were: (i) Loss of skeletal muscles in newborn mice bearing a mutation in the *myogenin* gene, based on Hasty et al. (1993) (see a translation to English of this APL paper in Appendix A); and (ii) The gene *hedgehog* mediates the polarizing activity in the limb buds, based on Riddle et al. (1993). The first APL-based curriculum was published and started to be implemented in schools for the first time during 1999 (Yarden and Brill 1999).

How the APL-Based Curriculum Was Initially Implemented

While developing the first version of the APL-based curriculum, Abraham Arcavi asked Anat: "What are they going to do with those articles in class?" The truth is that at that time there was no answer. Needless to say, this question is at the heart of the success of any such novel curriculum. Heda Falk joined the team at that time and started to design ways to implement the developmental biology curriculum in schools (Falk et al. 2003a; Yarden et al. 2001), and to investigate the implementation of the APL-based curriculum in numerous classes (Falk et al. 2005).

Additional studies carried out by Gilat Brill in schools were encouraging. Those studies showed that high school students tended to pose questions that reveal a higher level of inquiry thinking and uniqueness during and following learning using APL in contrast to learning using a textbook (Brill and Yarden 2003). Brill et al. (2004) also found a deeper level of comprehension of an APL text when high school students answered scaffolding questions. Ayelet Baram-Tsabari conducted a study that supported an early hypothesis that learning by using scientific research articles may be a way of developing among students a capacity for scientific ways of thinking among students. Ayelet was able to show that high school biology students who read an APL text better understood the nature of scientific inquiry and raised more scientific criticism of the researchers' work compared to students who read a popular scientific text (Baram-Tsabari and Yarden 2005).

How the APL Idea Was Further Developed

At the beginning of the year 2000 a new syllabus for biological studies in Israel was materializing. Due to the initial success of the APL-based curriculum, it was suggested that a new topic based on APL and termed a Research Topic be included. The objectives of the Research Topic were to: (i) strengthen students' understanding of the Nature of Science (inquiry skills, the history and philosophy of science, quantitative analysis of data, scientific communication); (ii) enable more frequent updates to the syllabus, avoiding the need to change the syllabus itself; (iii) represent the dynamics of biological discoveries by including cutting-edge articles as well as articles that are of utmost importance to the history of biological discoveries; (iv) elicit discussions about socio-scientific and bioethical issues; and (v) encourage teams of teachers to develop a Research Topic themselves as a means for professional development (Israeli Ministry of Education 2003).

Each Research Topic was to be based on knowledge acquired from learning the core topics (Ecology, Systems in the Human Body, and the Living Cell). Each topic comprised an introduction and three APL papers and was intended to be taught for a maximum of 30 h (Israeli Ministry of Education 2003). The three topics that were initially chosen were: (i) Developmental Biology (ii) Biotechnology and (iii) Biodiversity. It was suggested that teachers be able to choose one of the topics. Those three research topics might change, or the APL papers within the three topics might change, from time to time following the biennial advice of the Professional National Committee of Biological Studies in high schools in Israel. Two new APL-based curricula were developed, one in Biotechnology, designed at the Weizmann Institute of Science (Falk et al. 2003b), and a second in Biodiversity designed at the Science Teaching Center of the Hebrew University in Jerusalem (Amir 2005).

Table 1.2 The structure of the APL-based curriculum: Gene tamers – studying biotechnology through research (Falk et al. 2003b)

Section	Description
Part 1: Introduction	Classical vs. modern biotechnology
	Gene cloning in bacteria and in cell cultures
	Genetically modified organisms: plants and animals
	Biotechnology in service of medicine
Part II: Collection of research articles	The development of a biosensor for the detection of genotoxic materials
	Expression of the *Bt* bacterium toxin in chloroplasts of tobacco plants imparts resistance to insects
	Correction of ADA-SCID by bone-marrow stem-cell gene therapy

The structure of the APL-based biotechnology curriculum is identical to the structure of the APL-based developmental biology curriculum (Table 1.2). The introduction to the curriculum lays the groundwork for learning the APL articles by presenting basic concepts and processes in molecular biotechnology. Biotechnology is presented as a practically oriented, problem-solving endeavor. The fact is stressed that many biotechnological solutions, although beneficial, raise new problems. Students are invited to expose the possible drawbacks of present solutions and to suggest theoretical designs for better ones. The main part of the curriculum is composed of three adapted research articles that deal with three different topics: (i) Detection of genotoxic materials in water by bacterial biosensors based on Davidov et al. (2000); (ii) Promotion of plants' resistance to pests by expressing a bacterial toxin based on De Cosa et al. (2001) (see a translation to English of this APL in Appendix B); and (iii) Gene therapy of an immunodeficiency in humans based on Aiuti et al. (2002). These three articles were chosen to represent a variety of organisms used for biotechnological research; and a variety of stages in the biotechnological process, from basic research to field and clinical applications. Topics from cutting-edge research in biotechnology were selected, in the sense that they reached the public media and popular scientific articles have appeared based on them. Other criteria included their adaptability to the APL genre in terms of the presentation of the results, and the compatibility of the scientific background required with high school students' prior knowledge. The adaptation itself was more straightforward this time, as each APL was based on a single Primary Scientific Literature (PSL) paper. Choosing a suitable primary literature paper can be more challenging than the adaptation process itself.

The third APL-based curriculum in biodiversity is similarly structured to include an introduction and three APL papers. However, the APL papers in this curriculum are shorter than the papers in the other two curricula, and they include questions that request students to analyze the presented data instead of providing systematic descriptions of the actual results, as is customary for primary literature papers.

How the APL Acronym Was Coined

Even though the first APL-based curriculum was published in 1999 and the first paper that described the APL approach was published in 2001 (Yarden et al. 2001), the acronym was used for the first time only in 2008 (Falk et al. 2008). The delay was due to a long-lasting debate among the developers of the APL concept about whether the adapted papers can be referred to as primary literature per se or whether those papers represent a different text genre. Indeed all the characteristics of primary literature are represented in the adapted papers. However, there are two major differences between primary literature and APL that eventually convinced the opposers that the APL genre deserves a name of its own: (i) in contrast to primary literature, the writers of the articles are not (necessarily) or not only the scientists who carried out the research; and (ii) the target audience is high school students rather than scientists. The acronym APL was subsequently used in other works (e.g., Norris et al. 2009, 2012; Osborne 2009; Yarden 2009).

How the APL Idea Expanded

During the 2004 annual meeting of the National Association for Research in Science Teaching (NARST) that took place in Vancouver, the three of us met for the first time. Following a presentation on the existence of narrative explanations in primary science sources (Norris et al. 2004) in which we discovered we have mutual interests in the use of scientific texts for science learning in general and primary sources in particular, we decided to meet again to explore those possibilities. This meeting took place during the spring of 2006. At that time, Stephen was able to describe plans to conduct in Canada a study similar to the one reported in Baram-Tsabari and Yarden (2005). His curiosity was centered on whether the effects reported in the 2005 article could be replicated in Canada in a different language, subject, and topic area. The results of that study, since completed, provide confirmatory evidence of the effect of APL on promoting critical thinking (Norris et al. 2012). More recently, Shanahan et al. (2009) has been using successfully a version of APL, which she calls Hybrid Adapted Primary Literature (HAPL), with children in fifth and sixth grades. The 'H' refers to the fact that her adaptations contain a narration at the beginning about the scientists that helps set the personal and social context for the research.

What's Ongoing and Next?

The concept of using APL as part of the curriculum for learning biology in high schools is established in the Israeli syllabus. Two new APL papers have been prepared to replace the first two in the APL-based curriculum in Biotechnology

(Zer-Kavod and Yarden 2013a, b). One of the considerations in choosing the new papers to be adapted is the background knowledge that is provided in the current introductory part to the curriculum, which preferably need not change as frequently as the APL papers. In addition, APL papers for each of the core topics in the syllabus are planned, thus enabling students that did not learn the APL-based curriculum to be exposed to the APL genre. Those papers may enable biology majors (11th–12th graders), who are required to submit an inquiry project as part of their matriculation examination, to be exposed to the APL genre that may serve as a model for the written part of their inquiry project. In addition, APL papers are being prepared for biotechnology majors (11th–12th graders) who are carrying out inquiry projects as part of their matriculation examination. As well, shorter APL papers for the junior-high school population (7th–9th graders) are incorporated in a new curriculum in biology (Ariely and Yarden 2013).

As yet there is no formal recognition of APL in the Canadian science curriculum. Science education is a provincial jurisdiction; it is not certain that if APL were adopted in one province that it would spread to others. At this stage, materials are made available for teachers to use wherever they can find a place within the curriculum. For instance, the introductory grade 12 calculus class in Alberta, contains an optional unit on applications of mathematics to biology. The West Nile Virus module (see Chap. 9) is a perfect choice for teachers wishing to avail of that option.

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