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Text Genre as a Factor in the Formation of Scientific Literacy

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Abstract: Learning using primary literature may be a way of developing a capacity for scientific ways of thinking among students. Since reading research articles is a difficult task for novices, we examined the possible benefits of learning using primary literature versus secondary literature, particularly with respect to their influence on the creation and formation of scientific literacy. We report on a comparison between four groups of high school students, each with differing degrees of prior knowledge in biology, who read a domain-related text written in either the scientific research article genre (adapted primary literature) or the popular-scientific genre (secondary literature). Although there was no significant difference in the students' ability to summarize the main ideas of each text, indicating that there was no eminent distinction in their content, we found that students who read adapted primary literature demonstrated better inquiry skills, whereas secondary literature readers comprehended the text better and demonstrated less negative attitudes toward the reading task. Since the scientific content of the two texts was essentially identical, we suggest that the differences in students' performances stem from the structure of the text, dictated by its genre.
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The need to create a scientifically literate citizenry is a widely accepted educational goal (American Association for the Advancement of Science, 1990; Laugksch, 2000; Report of the Superior Committee on Science Mathematics and Technology Education in Israel, 1992; Uno & Bybee, 1994). The question of what constitutes scientific literacy, or what a literate person should know or be able to do, is far more controversial (American Association for the Advancement of Science, 1990; Bybee, 1997a; Harlen, Raizen, & deRoo, 2000; Laugksch, 2000; National Research Council, 1996). We chose to use Shamos's definitions for functional and ''true'' scientific literacy (quotation marks in the original) (Shamos, 1995) as our operational definitions of scientific literacy. Functional scientific literacy is characterized by the ability to converse, read, and write coherently in a nontechnical but meaningful context. This definition should not be conflated with the Biological Sciences Curriculum Study (BSCS) definition of functional biological literacy, which concerns the use of biological vocabulary based on memorized responses (Uno & Bybee, 1994). However, a functional-literate person, according to Shamos, lacks an

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understanding of the fundamental role played by theories in the practice of science and of the unique processes that characterize it. ''Scientific habits of mind'' such as logical reasoning, the role of experiments, reliance on evidence, the ability to think critically and other elements of scientific investigation are all characteristics of ''true'' scientific literacy (Shamos, 1995). In addition, the ''true'' scientifically literate individual has the ability to use those scientific ways of thinking for individual and social purposes (American Association for the Advancement of Science, 1990; Hurd, 1998; Shamos, 1995).

If we want the future citizen not only to be able to possess and use scientific knowledge, but also to take part in decision-making with regard to the application of science to everyday life (Hurd, 1985), we must teach today's students not only what science can do, but also how science is done. Therefore, teaching science should be consistent with the nature of scientific inquiry (American Association for the Advancement of Science, 1990). This includes starting with questions about phenomena rather than with answers to be learned (American Association for the Advancement of Science, 1989).

One possible way of developing this capacity for scientific ways of thinking might be through the use of scientific research articles for learning. Since the scientist who did the research is also the one describing it in the article, this text is also termed ''primary literature.'' The use of primary literature for learning might give the functional-literate person some important elements of ''true'' scientific literacy. Primary literature not only closes the gap between public knowledge and the frontiers of scientific inquiry, it can also develop the following components of scientific literacy: acquaintance with the rationale of the research plan; exposure to research methods and their suitability to the research question; acquaintance with the language and structure of scientific communication; development of the ability to critically assess the goals and conclusions of scientific research; exposure to problems in a certain discipline and acquaintance with the continuity of the scientific research process (Yarden, Brill, & Falk, 2001). Primary literature may instruct students on the nature of scientific reasoning (Muench, 2000) and help to teach complementary aspects of scientific investigation and writing (Kuldell, 2003). In addition, students may find reading research articles a novelty and a challenge (Epstein, 1970), and may also identify with the researchers' quest. Whereas textbooks concentrate on presenting the conclusions of scientific research, science journals also define problems, as well as describe and justify methods (Norris & Phillips, 1994).

Following this rationale, the new syllabus for high school biology studies in Israel contains a requirement for the comprehension and analysis of research articles by senior biology majors (see Methods). More specifically, as of 2006, all biology majors will be examined on the subject matter they learned through the reading of adapted primary literature, as part of the national matriculation examinations (Israeli Ministry of Education, 2003).

However, learning through research articles is both a challenge and a difficult task for the novice (Janick-Buckner, 1997; Smith, 2001; Yarden et al., 2001). Despite the fact that many scientists would state that a research article is easier for them to follow, and that it is more organized and clearly structured, the research article is much more permissive to information gaps than a popular article and lacks the reader-friendly use of metaphors, analogies and examples.

Scientific research articles and popular-science articles belong to two different genres. Genres are text types defined by function, sociocultural practices, and communicative purpose (Ravid & Tolchinsky, 2002). Two major categories of text genres are expository text, a text whose primary purpose is to expose information or ideas and narrative text, which is usually written to entertain more than to inform, and is easier to comprehend (Grasser & Goodman, 1985). A scientific research article is included in the expository text category, whereas a popular-science article can be considered a mixed text, found somewhere on a scale between expository and narrative text, due to its episodic story-telling parts that include characters and events. One reason genres are important is because they appear to elicit varied processing (Alexander & Jetton, 2000).

Scientific texts, as a subgenre of the expository text, are typically difficult to read because they are written in ''scientific language,'' a ''jargon'' that has the effect of making the learner feel excluded and alienated from the subject matter (Halliday, 1993). In scientific writing there is much use of the passive voice, of abstract nouns in place of verbs, and of verbs of abstract relation in place of verbs of material action (Lemke, 1990). According to a statistical formula for the objective measurement of readability, scientific magazines achieved the lowest score on the ''reading ease'' and ''human interest'' score, ranking them as ''very difficult'' and ''dull,'' respectively (Flesch, 1948). It also should be noted that the familiar and easy-to-handle structure of the research article is well known to scientists, but not to high school students. Therefore, it is interesting to examine the possible benefits of learning using scientific research articles versus popular-scientific texts, in particular their influence on the creation and formation of scientific literacy.

Although a number of scientific literacy assessment tools are available (Aikenhead & Ryan, 1992; Champagne et al., 2000; Korpan et al., 1994; Laugksch & Spargo, 1996a, 1996b; Schleicher, 1999), none of them deals with comprehension of scientific research articles and most of them do not use high school biology content in their assessment process. We chose to assess scientific literacy through the investigation of students' understanding and interaction with content-related tasks, rather than spelling out the knowledge, skills and attitudes that students should possess as a consequence of their whole school experience (American Association for the Advancement of Science, 1993; National Research Council, 1996).

In the present work, we attempted to determine how adapted primary literature and secondary literature influence the creation and formation of scientific literacy among high school biology students. We hypothesized that secondary literature would generate a better understanding of the text among high school students due to its greater explanatory coherence, whereas adapted primary literature would better convey to its readers a knowledge of the syntactic structure of the discipline, which would help them understand how biological research is done.

Strategy

As a platform for this research, we used a breakthrough research article that strongly correlates to science, technology, and society (S–T–S) issues. The work was carried out as part of an effort to confront students with a current real-world issue impacting society (Yager, 1993), with the understanding that inquiry into authentic questions, preferably scientific topics that have been highlighted by current events, is one of the central strategies for teaching science (National Research Council, 1996).

We chose an article that describes the design of a polyvalent inhibitor to the anthrax toxin (Mourez et al., 2001), as a basis for writing two articles suitable for the high school students' cognitive level. The modified articles were written in two text genres: the first was a research article in which the basic typical structure of the original article was retained, as well as the use of passive voice, as previously described in detail (Yarden et al., 2001). Since we retained the common structure of a research article, as well as the authentic results and illustrations, and since the modifications were only meant to simplify the text, but not to change it significantly, this modified version of the research article is henceforth referred to as ''adapted primary literature'' (Yarden et al., 2001). The second version was written as a popular-scientific article by one of the authors, who is an active science journalist and has gained a lot of experience in writing and editing in this genre for the print mass media. This version provided easier fluent readability while almost completely retaining the same data; this article is henceforth referred to as ''secondary literature.''

Biology is one of the most dynamic research disciplines within the natural sciences, and new research discoveries are published almost daily. Most of these discoveries are published in scientific journals in English. Israeli students, for whom English is not their mother tongue, cannot be presented with an authentic English text. Since our goal was to retain the same scientific content in both adapted primary and secondary literatures, we could not use a random popular-scientific article from the available popular press in Hebrew. Therefore, we had to translate the research article that we used into Hebrew and to compose a popular-science article describing it. Appendix A presents paragraphs from both adapted texts and the original article.

Learning from texts is a complex skill that involves complex interactions between the reader's mind and the text (Holliday, Yore, & Alvermann, 1994). Therefore, our group chose to use multiple approaches in order to shed some light on the process of learning from research articles. To obtain rich and in-depth data, we used a qualitative approach to characterize the way in which two high school biology students read a research article, to determine possible reasons for their difficulties, and to identify the reading stages and reading strategies used by the two students (Brill, Falk, & Yarden, 2004).

We decided to use a quantitative approach to this research, although these survey methods homogenize important distinctions (Messer-Davidow, 1985). All Israeli high school students who choose to major in biology (see Methods for details) will have to read adapted primary literature as part of their learning process. Therefore it is important to probe the ways in which the broad population is affected by this new educational effort.

In this research, one group of students received the adapted primary literature text and another group received the secondary literature text. Students' scientific literacy was not assessed in comparison to a particular, predetermined model, but compared with the achievements of the other group. Students' achievements were assessed using diverse paper-and-pencil methods in order to gain a multidimensional perspective (Laugksch, 2000) on the way in which text genre influences the formation of students' scientific literacy. Following the reading of one of the two texts, four types of open-ended items were used as assessment tools:

1. Communication of the main ideas and conclusions that were detailed in the article was assessed in the format of a written abstract. Analysis of what is included and what is omitted in a student's written summary tells us something about what has been understood from the text (Garner, 1982) and provides some valuable insight into what the students considered the most important points in the experiment described in the article.
2. Reading comprehension and acquisition of biological knowledge were tested in the format of content-based True/False (T/F) questions. Students were also required to explain each of their responses. During analysis, the questions were sorted into two groups. Provision of full answers to the first group (which consisted of seven questions) required reading comprehension, while providing full answers to the second group (which consisted of four questions) also required the ability to infer new information. This task demanded the generation of elaborative inferences, not only required inferences, which simply stem from local coherence of the text (Fincher-Kiefer, 1996). The first group of questions can also be described as dealing with the textbase level and the other with the creation of a situation model through the use of prior domain knowledge, as previously suggested by Kintsch (1989).
3. An understanding of the processes and methodology of scientific inquiry was demonstrated in the format of three open questions. Scientific processes which include the collection and interpretation of data, and the derivation of conclusions (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), as well as the combination of those processes with scientific knowledge, use of scientific reasoning and critical thinking abilities

(Bybee, 1997b; National Research Council, 1996), served as the theoretical framework for measuring the scientific inquiry skills in this section.

4. Students' attitudes toward learning using adapted primary and secondary literature were assessed using a series of 11 statements concerning the reading task: four of them were positive and seven negative. Students were asked to rate each of the 11 statements on a Likert-type scale ranging from 1 to 6 (1 = strongly disagree, 6 = strongly agree).

The first and second sections of the questionnaire were aimed at measuring students' functional literacy, while the third dealt with elements of scientific investigation, in order to examine students' "true" scientific literacy (Shamos, 1995). The fourth section accounts for students' attitudes and learning styles.

The full translated questionnaire is presented in Appendix B.

Methods

Subjects

High school biology students ($n = 272$) participated in the experiment for biology class credit. The students were gathered from 11 classes chosen from four different academic urban and suburban-type high schools in Israel. All four schools are attended by a culturally nondeprived population. All subjects learned the same curriculum in biology, since Israel has a centralized education system. We can assume that the students' ability to read and write in Hebrew was similar for all four schools. The schools and classes were chosen according to the teachers' initiative and motivation to take part in what is still an experimental program.

Biology class grades were obtained from the teachers of 6 out of the 11 classes that participated in the experiment. The five remaining teachers felt it would be inappropriate to hand over their students' grades to researchers from outside the school administration. From the grades that we obtained, we learned that the average biology class grade for the males was 81.8 and for the females was 80.6, out of a maximum score of 100. Two hundred-sixty questionnaires out of a total of 272 were gender-identifiable (see questionnaire analysis for details)—180 of them belonged to female students and 80 to male students. This ratio is close to the 1.9:1 female-to-male ratio found in classes in Israel where students major in Biology, according to B. Agrest, Chief Inspector of Biology Education in Israel (personal communication, October 23, 2002).

About one half of the students who participated in the experiment were biology majors. In Israel, at the end of the tenth grade, students choose to major in at least one scientific or nonscientific topic, which is evaluated in a national matriculation examination. The syllabus for the biology-major studies in Israel requires 450 hours of teaching (Israeli Ministry of Education, 1991) and includes, in addition to basic topics, advanced topics that are aimed at reflecting the dynamics of biological research and discovery. The new syllabus also includes the use of adapted primary literature by the students as part of their learning process (Israeli Ministry of Education, 2003).

Biology majors study biology for a period of three years. Therefore, twelfth-graders have more opportunities to acquire diverse biological concepts and principles and to elaborate their knowledge regarding the techniques being used in biological laboratory research during their "hands-on" assignments compared with tenth and eleventh-graders. Prior knowledge can be explained as a combination of the learner's pre-existing attitudes, experiences, and knowledge (Bransford, Brown, & Cocking, 1999); therefore, we can assume that grade level in this research estimates prior knowledge in biology.

To separate the effects of prior knowledge from those of text genre, subjects were divided into four groups according to their estimated prior knowledge in biology: twelfth-grade biology majors

($n = 27$, one class), eleventh-grade biology majors ($n = 115$, five classes), tenth-graders with relatively high knowledge (HK) in biology ($n = 49$, two classes) and tenth-graders with relatively low knowledge (LK) in biology ($n = 81$, three classes). The tenth-graders were classified at the class level: two classes were classified as high-knowledge (HK) and another three as low-knowledge (LK). The classification was initially done according to the biology teachers' estimations and was later verified by Duncan grouping statistical test of the comprehension and inquiry sections of the questionnaire (data presented at Appendix C).

Materials

The two texts were written based on the article "Designing a polyvalent inhibitor of anthrax toxin" that was published in *Nature Biotechnology* the same year (Mourez et al., 2001). The article was translated into Hebrew and adapted into two different versions, preserving most of its content but varying in style: adapted primary literature (1546 words), and secondary literature (828 words). Note that both texts yielded very similar performances on the abstract assignment, where seven main ideas had to be identified and summarized (see Results). This indicates that there was no pronounced distinction between the content of the adapted primary and the secondary literatures. The big difference in word count stems from two reasons: genre-related repetitions in the adapted primary literature (e.g., describing an experiment in the Materials and Methods section, recalling it in the results section, and discussing it in the discussion section of the article), and the omission of one experimental method (selection of peptides by phage display) from the secondary literature text. There was no reference in the questionnaire to that specific method.

The same questionnaire was used for both versions, testing the students for their ability to write an abstract, their reading comprehension and inferential abilities, their inquiry skills and their attitudes toward the reading task (as detailed earlier).

The instruments (texts and questionnaire) were validated by six experts: two high school biology teachers who had already gained experience in the implementation of adapted primary literature, two science teaching researchers at the Weizmann Institute of Science, a biologist, and an experimental psychologist who had specialized in psycholinguistics (since the focus of this study is the use of texts for learning). The reliability of the questionnaire was analyzed using the Alpha Cronbach coefficient and all values appeared to be $\geq .8$. The analysis results are shown in Table 1.

Table 1
Questionnaire reliability analysis

Section	Assessment tool	No. of items	Alpha Cronbach coefficient
A	Abstract writing[a]	7	0.8
B	Content-based T/F questions[b]	22	0.84
C	Open-ended questions[c]	6	0.83
D	Students' attitudes[d]	11	0.86

[a]Abstracts were examined for the presence of seven main ideas appearing in the text.
[b]Students had to explain each of their answers. Analysis was done for all answers and explanations.
[c]Each question was coded first as answer/did not answer and then as relevant answer/nonrelevant answer. The analysis did not include the full scoring scheme ranging 0–5 or 0–4 presented in Table 2.
[d]The scores of the negative attitudes were reversed.

Procedure

Subjects participated in the experiment as part of their regular biology class during the 2001–2002 school year. The two different texts, adapted primary and secondary, were randomly assigned to the students in each class. Teachers were instructed to dedicate two lessons in a row to the task, including the break between lessons (for a total of 95–105 minutes). The task was performed individually and teachers were instructed not to answer questions concerning the information presented in the texts during the activity.

Questionnaire Analysis

The questionnaires were graded in the following manner:

1. The abstracts were examined for the presence of seven main ideas appearing in the text: (i) *Bacillus anthracis* secretes a toxin that has a damaging effect on the body; (ii) the toxin is made up of three proteins; (iii) the researchers tried to prevent/delay the construction of the toxin; (iv) the researchers discovered a peptide that delays the interaction between the proteins that make up the anthrax toxin; (v) from that peptide they built a more effective inhibitor; (vi) the inhibitor was successfully tested in vitro and in vivo; and (vii) as a result of the success, one can hope that the inhibitor or any other substance developed in a similar way will serve as a cure for anthrax. Young adolescents find the production of written expository texts a difficult challenge. Indeed, constructing an expository piece of discourse requires the writer to focus on a clear and explicit discourse topic, and to manifest pre-planning, careful organization of textual information, and extensive common knowledge. Even among well-educated, although nonexpert, adults, narratives are more developed and better constructed than expository texts (Ravid, 2004). Therefore, students' writing literacy, as expressed in their spelling, grammar and rhetorical ability, was disregarded as much as possible during scoring.
2. The answers to the T/F questions and their explanations were graded as either right or wrong.
3. The answers to the scientific inquiry section were graded according to a predetermined scale based on relevance, use of scientific ideas and prior knowledge, detailing, correctness, originality and integration of information from different sections of the article. Scoring schemes and examples of students' responses are presented in Table 2.
4. Attitudes toward the nature of the task were assessed using a Likert-type scale (ranging from 1 to 6).

Gender classification was done using students' answers to the open questions. Hebrew is a gender-defining language, therefore the subjects automatically reveal their gender through the use of verb gender indicators, e.g., "I am checking" will be translated as *ani bodeket* (feminine)/*ani bodek* (masculine).

Statistical Analysis

Unless otherwise indicated, the one-tailed unpaired *t* test procedure and Pearson correlation statistical test were used. Homogeneity was tested using Bartlett's test for homogeneity of variance (Winer, 1971). Correlation between adapted primary readers' attitudes (see Figure 5A) and learning styles (see Figure 5B) to their prior knowledge was calculated using class averages for the different variables and their prior knowledge group.

Table 2

Scoring schemes and examples of students' responses[a] for the scientific inquiry section

Q1.[b] Which experiments would you conduct now in order to test the medicine's efficiency further?

Score	Indicator[c]	Example
0	Nonrelevant response or no response at all	"It seems to me that the doctors understand this better than me, and they're doing the experiments that should be done" (LK 10th-grader)
1	Illogical idea	"I would inject it into someone who has a similar blood-type to the monkeys" (LK 10th-grader)
2	Logical idea for an experiment, but no details on the variables being tested	"It is very important to verify the result in more animals, not only rats. Maybe in cattle" (11th-grader)
3	A doable idea for an experiment	"I would conduct experiments on other animals, structurally closer to humans–for example, monkeys, in order to test the inhibitor's effect on cells that are closest structurally to human cells" (11th-grader)
4	A detailed suggestion for a doable experiment	"In order to continue the testing of the medicine's effectiveness I would. . .divide the rats into groups. To the first group I would inject the toxin and the inhibitor together. To another group I would inject the toxin and after some time the inhibitor as well. To the next group I would inject the toxin and after a longer time than the second group, I would inject the inhibitor." (11th-grader)
5	Several suggestions for doable experiments	"Firstly, I would test the inhibitor's effectiveness in another animal, additional to the rats, by injecting the inhibitor with the parts of the toxin and checking the inhibitor's influence on the appearance of symptoms. Secondly, I would conduct a similar experiment on rats from the same strain that were used in the research, that are not in normal physical shape, in order to check the inhibitor's effect on their health" (12th-grader)

Q2. Do you have any scientific criticism of the researchers' work? Are there any experiments that you would have conducted differently?

Score	Indicator[d]	Example
0	Nonrelevant criteria for evaluation or no response at all	"I wouldn't use animals in the experiment" (LK 10th-grader)
1	Relevant criteria for evaluation with no explanation	"Maybe they could have checked if the use of the inhibitor has other implications" (11th-grader)
2	Relevant criteria for evaluation with specific reference to the research	"I would do the experiments on animals that have similar cellular structure to humans" (11th-grader)
3	Relevant criteria for evaluation with specific reference to the research and suggestion for rectification	"I have criticism about the dosage of the inhibitor that was used (12 and 75 [nanomoles]) in the trial with the rats, the difference is too big, so you can't tell at what stage the inhibitor prevents the poisoning. Maybe the poisoning is prevented at a dosage of 40 and there was no need to use 75. I would have tried more dosages in order to know when exactly the intoxication is prevented" (11th-grader)

Table 2
(Continued)

Score	Indicator[d]	Example
4	Criticism based on integration of information from different parts of the article or on connection to prior knowledge	"The researchers succeeded in developing an inhibitor that would prevent the toxin's parts to assemble together, penetrate the cell and cause harm to it. However, the toxin that already entered the cell is not affected by the inhibitor. In other words, the inhibitors' activity isn't so much better than the effect of the antibiotic that kills the bacteria but not the toxin that already entered the body" (11th-grader)

Q3. Can you think of any other applications for the technique that was used by the researchers to develop the inhibitor?

Score	Indicator	Example
0	Nonrelevant response or no response at all	"On a dead animal" (LK 10th-grader)
1	An idea with no explanation at all	"Developing drugs for different diseases" (11th-grader)
2	An idea with minimal explanation	"I think this technique can be used in the development of every drug that causes this complication in protein and enzyme binding" (11th-grader)
3	An idea with minimal explanation and connection to prior knowledge	"I think this technique can be used in order to prevent enzymes from binding when a person is infected with the AIDS virus" (11th-grader)
4	A detailed suggestion with explanation of the action mechanism	"In every case...that we want to prevent a process in which two substances are connecting to each other in a certain area (some kind of active site) and it is possible to find another material that would replace one of the substances due to molecular similarity and would connect to the active site instead of the original substance" (11th-grader)
5	A detailed suggestion with explanation of the action mechanism and connection to prior knowledge	"In cases where the damage is caused by the binding of two different enzymes and the binding can be prevented by another factor. e.g.: In brain injuries damage is sometimes caused to the memory.... The degeneration of the nerve cells worsens because of the binding of metals like Ca^{2+} and Cu^{2+} that are released from the cells with the free radicals. A drug that would absorb the surplus metals would prevent their binding" (11th-grader)

[a]The examples are translated verbatim quotes.

[b]Q1, Q2, and Q3 refer to questions 1–3 in section C of the questionnaire, respectively.

[c]Ethical and moral issues were completely disregarded during answer grading. Scores were given only with respect to the biological and experimental content of the answer.

[d]Only use of internal criteria for evaluation was expected from students who suggested criticism regarding the researchers' work, since students have no knowledge of the standards by which such works are generally judged and are not able to compare the research to other works in the field (Bloom et al., 1956), therefore they can not apply external criteria to their evaluation.

When presented on the same scale, performances in items with different maximal scores were divided by the maximal grade for that item in order to achieve a relative score (see Figures 1, 2, 3 and 4).

Results

Learning Using Adapted Primary Versus Secondary Literature

To evaluate the differences between learning using adapted primary versus secondary literature, we analyzed 272 questionnaires filled in by high school biology students who had read one of the two texts. Although there was no significant difference in the students' ability to summarize the main ideas of each text (two-tailed: $t = -1.46$, $p = .14$), there were significant differences in the students' ability to demonstrate their comprehension and inquiry skills (Figure 1). Students who read the adapted primary literature presented a better understanding of the processes and methodology of scientific inquiry than the ones who read the secondary literature ($t = 1.66$, $p = .049$), while the latter demonstrated better comprehension of the text ($t = -1.63$, $p = .05$) than the adapted primary literature readers. Thus, our initial hypothesis that secondary literature would generate a better understanding of the text, while adapted primary literature would help understand how biological research is done, was indeed verified. To

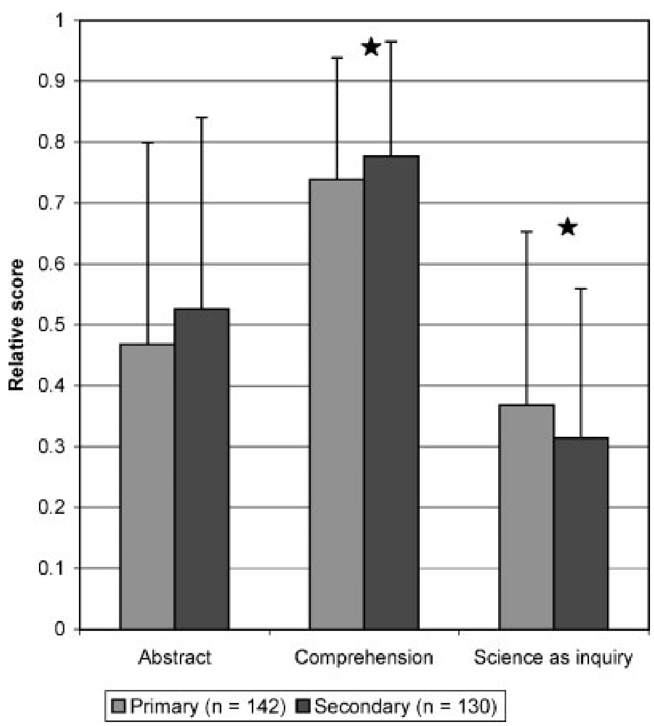

Figure 1. Comparison between learning through a scientific research article and a popular-science article in the 10th–12th grades: 272 high-school biology students were tested for their ability to write an abstract (Abstract), their reading comprehension (Comprehension) and their inquiry skills (Science as inquiry), after reading a scientific research article (Primary) or a popular-science article (Secondary). Significant differences are marked: *$p < 0.05$. The data were analyzed using a t-test.

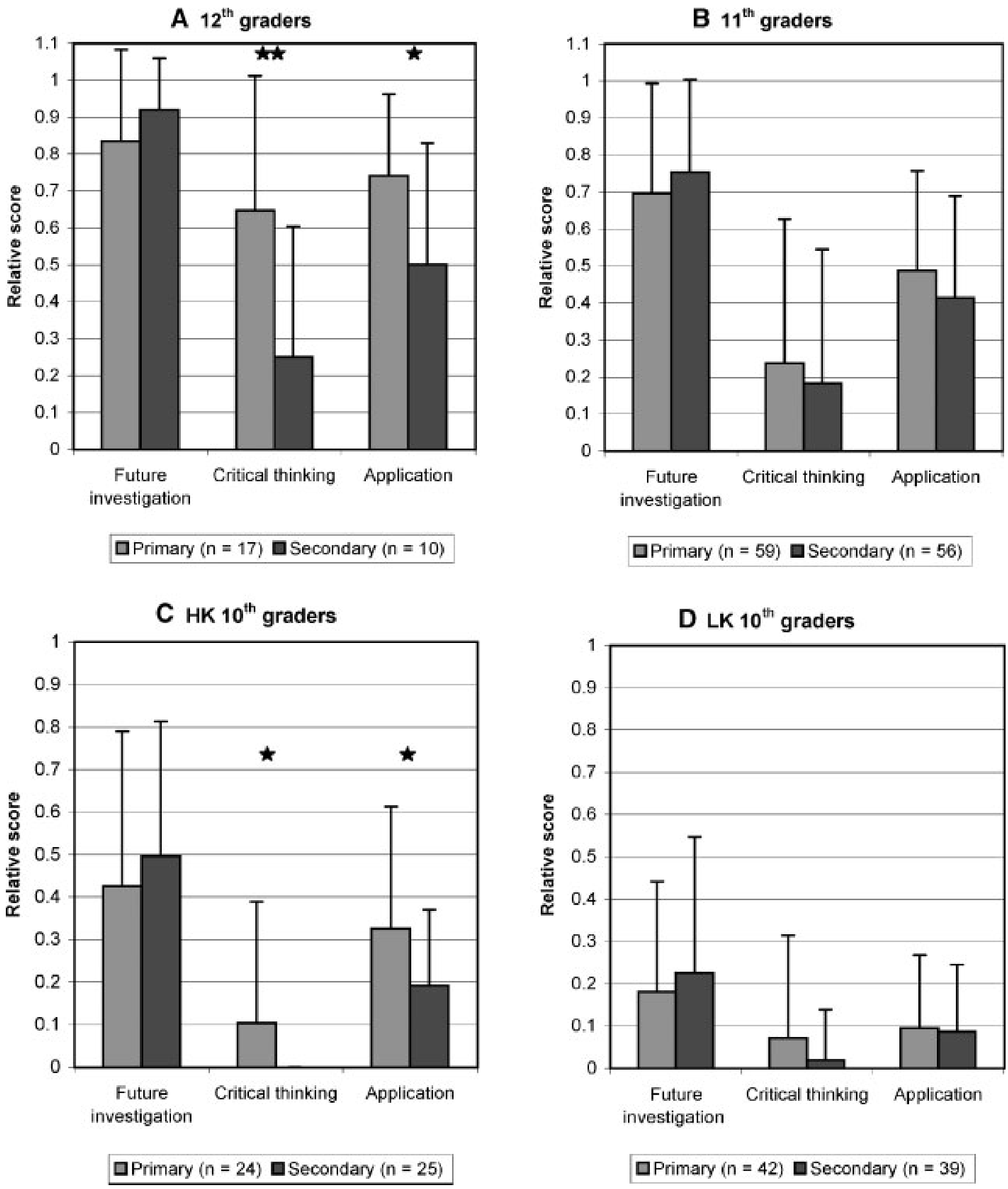

Figure 2. Demonstration of inquiry skills after reading a scientific research article and a popular-science article in the 10th–12th grades: High-school biology students were tested for their ability to suggest what should be the next experimental step (Future investigation), to evaluate the work (Critical thinking) and to offer applications for the technology described in the paper (Application) after reading a scientific research article (Primary) or a popular-science article (Secondary). Significant differences are marked: $*p < 0.05$, $**p < 0.01$. The results of 12th-grade students (A), 11th-graders (B), 10th-graders with relatively high prior knowledge (HK) in biology (C) and 10th-graders with relatively low prior knowledge (LK) in biology (D) are shown. All panels were analyzed by *t*-test. Scales for A and B are higher in order to allow a clear view of the standard deviations.

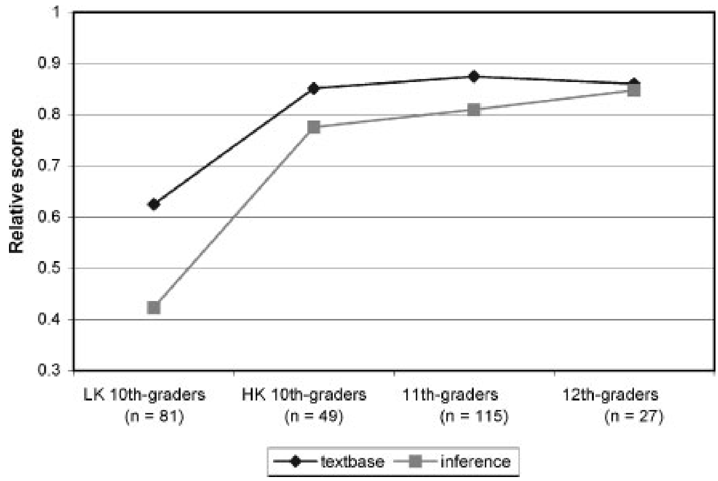

Figure 3. Students' relative scores in textbase versus inference questions. High-school students were divided into four groups according to their grade and estimated prior knowledge in biology. Students responded to 11 items concerning the article they had read: responding to 7 of the items required only reading comprehension (textbase), while responding to the remaining 4 items required analysis and inference abilities (inference).

understand this initial observation further, we performed detailed analyses of each of these components, namely understanding of the processes and methodology of scientific inquiry, as well as text comprehension, among high school students who had read either adapted primary or secondary literature texts.

Understanding Science as Inquiry Using Adapted Primary Versus Secondary Literature

The understanding of the processes and methodology of scientific inquiry was tested using the format of three open questions. In two of the three questions, students who had read the adapted primary literature text did significantly better than the ones who had read the secondary literature text: the former raised more scientific criticism of the researchers' work and methodology ($t = 2.8$, $p = .003$) and suggested more future applications of the technology described in the article ($t = 2.6, p = .005$). There was no significant difference in the students' ability to propose the next experimental step ($t = -.97, p = .17$).

To examine the effect of prior knowledge on students' inquiry skills, we compared the average scores obtained in that part of the questionnaire by the four prior-knowledge groups. The best scores were achieved by the twelfth-graders, followed by the eleventh-graders and then the HK tenth-graders. Tenth-graders with relatively low prior knowledge in biology were always the weakest (Figure 2).

In two of the three questions, the Duncan grouping test indicated a separate characteristic for each prior-knowledge group. The exception, scientific evaluation of the work, divided the students into three groups, keeping the tenth-graders together (data presented in Appendix D). Note that although the scores obtained in the task are very different among the four prior-knowledge groups, the overall pattern is very similar: the students who read the adapted primary literature demonstrated better critical thinking and application abilities than the students who read the secondary literature, whereas the latter offered more detailed ideas for future investigations (Figure 2).

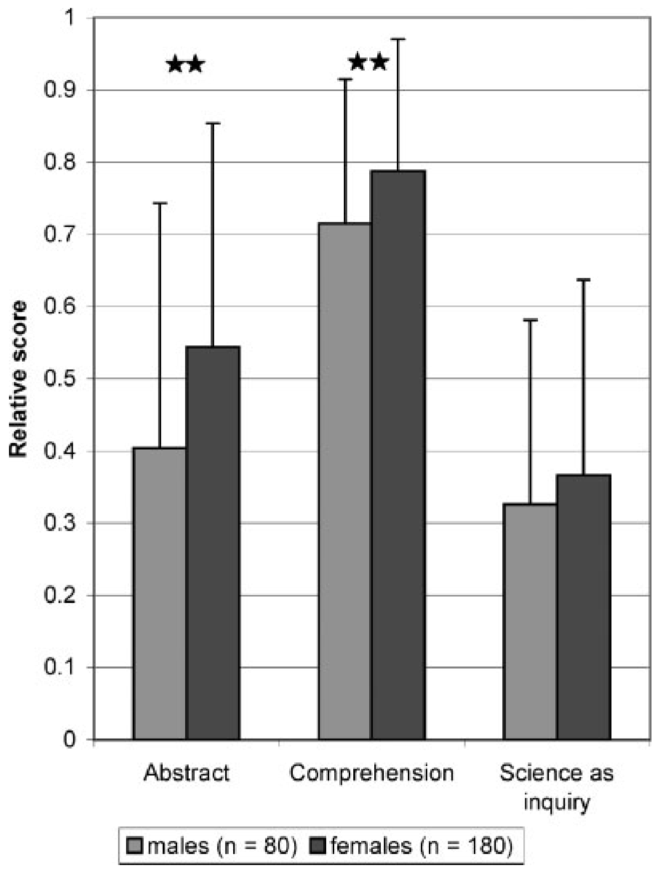

Figure 4. Comparison between male and female performance in a text-based task. 10th to 12th-grade biology students were tested for their ability to write an abstract (Abstract), their reading comprehension (Comprehension) and their Inquiry skills (Science as inquiry), following an individual text-based learning task. Significant differences are marked: $^{**}p < 0.01$. The data were analyzed by *t*-test.

Furthermore, in all four groups, students found it easier to come up with an idea for the next experiment than to find another application for the technology, and for all of them, raising scientific criticism was the hardest demand (Figure 2).

Grading scales for the scientific inquiry questions and examples of students' responses are presented in Table 2. These examples are translated verbatim from quotes selected from the participants' responses at all prior knowledge and grade levels.

Prior Knowledge and Heterogeneity Within the Knowledge Groups

Homogeneity of the scores within each knowledge group grew with prior knowledge and grade, in all but two items of the questionnaire. The exceptions, in which heterogeneity within the knowledge group increased with prior knowledge and grade, were the critical thinking and application items from the scientific inquiry section (Table 3).

The observed increase in homogeneity can be explained by the fact that among eleventh- and twelfth-grade biology majors, almost all of the students were capable of successfully completing

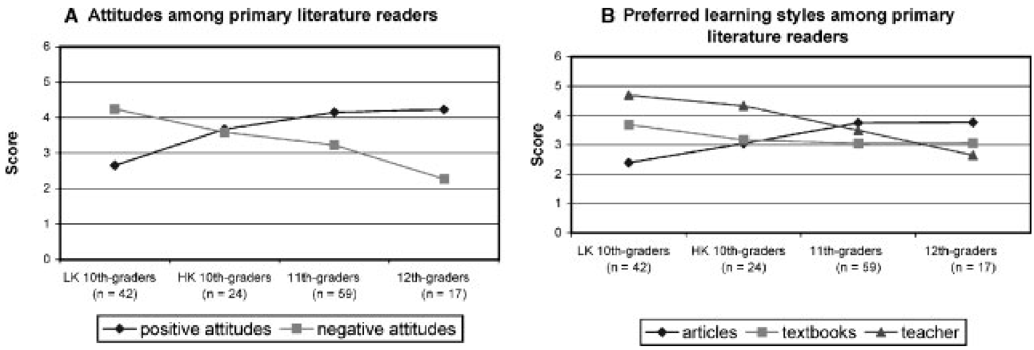

Figure 5. Students' attitudes towards learning using primary literature in the 10th–12th grades. High-school biology students responded to a series of 11 statements concerning a reading task written in the primary literature genre. Students were asked to rate the statements on a Likert-type scale ranging from 1–6 (1 = strongly disagree, 6 = strongly agree). A. Positive and negative attitudes among primary literature readers were analyzed based on 4 positive statements (positive attitudes) and 7 negative statments (negative attitudes). B. Attitudes towards different learning styles were analyzed based on 3 statements: "I would like to learn more subjects using articles" (articles); "I would rather study using a textbook" (textbooks) and "I prefer that the teacher explain, so I won't have to read by myself" (teacher).

the task, while in the tenth grade only a gifted and motivated few broadened the otherwise limited scale of the grades. When the task is a more complicated one (as can be seen in the relative scores of the critical thinking and application items), the situation is reversed: among tenth-graders, almost none of the students were capable of completing the task, while biology majors demonstrated very different degrees of performance and therefore presented high heterogeneity in those performances.

Comprehension: Textbase Versus Inference Questions

Comprehension and acquisition of biological knowledge were evaluated using open-ended content-based True/False (T/F) statements that required either reading comprehension or reading comprehension and inference ability. For LK and HK tenth-graders as well as for eleventh-

Table 3
Prior knowledge and heterogeneity of the scores[a] obtained within the knowledge groups

Item type	LK 10th-graders	HK 10th-graders	11th-graders	12th-graders	Bartlett test
Abstract	4.49	5.64	3.06	2.8	8.84*
Comprehension	4.88	1.75	1.35	0.89	52.85* * * *
Science as inquiry: Future investigation	2.11	2.88	1.91	1.15	6.98
Science as inquiry: Critical thinking	0.6	0.67	2.26	2.62	52.73* * * *
Science as inquiry: Application	0.68	1.5	1.86	2.05	23.75* * * *

Significant at the: * .05, ** .01, *** .001, **** .0001 level.
[a]Variances of the various knowledge groups for different items are shown. Homogeneity was tested using the Bartlett test for homogeneity of variance.

graders, answering textbase questions proved to be easier than answering inferential questions (two-tailed paired t test, $t = 8.51$, $p = .0001$; $t = 2.61$, $p = .012$; $t = 4.07$, $p = .0001$, respectively) (Figure 3). However, differences in the scores decreased gradually, as the level of prior-knowledge increased (the difference in eleventh-graders' ability to answer textbase and inference questions is smaller than HK tenth-graders; however it is more significant due to differences in standard deviations); twelfth-graders were equally capable of answering both types of questions ($t = .46$, $p = .65$).

Gender Equity

Two hundred-sixty questionnaires out of the total 272 were gender identifiable. In the comparison between the two genders, we verified that although there were no significant differences between male and female students' high school biology class grades (see Methods), there were differences in their ability to summarize the main ideas of the text in an abstract and to comprehend the text as expressed in their answers to T/F questions and in their explanations. Female students scored significantly higher in those two parameters (two-tailed: $t = -3.27$, $p = .001$; $t = -2.87$, $p = .005$, respectively), compared with male students (Figure 4). However, there was no significant difference in students' inquiry skills between genders (two-tailed: $t = -1.14$, $p = .25$).

Text Genre and Students' Attitudes

A comparison between students' attitudes toward each of the two texts revealed no significant difference in students' positive attitudes toward the task (two-tailed, $t = -1.71$, $p = .09$), standing at an average of 3.64 (adapted primary literature) and 3.91 (secondary literature) out of 6. However, there was a highly significant difference in the students' negative attitudes: the students who read secondary literature expressed considerably less negative attitudes than the students who read the adapted primary literature (two-tailed, $t = 4.65$, $p < .0001$). Negative attitudes like the ones expressed by the adapted primary literature readers may affect future citizens' attitudes toward independent reading of popular-scientific literature later in life.

Students' attitudes toward learning using adapted primary literature in the tenth to twelfth grades are shown in Figure 5A. Note the increase in positive attitudes and the decrease in negative ones correlated to the increase of prior knowledge in biology ($r = .89$, $p = .0007$; $r = -.78$, $p = .008$, respectively). Only among LK tenth-graders were the negative attitudes stronger than the positive ones. Among biology majors—the target audience for learning using adapted primary literature according to the new syllabus for high school biology studies in Israel (Israeli Ministry of Education, 2003)—the average positive attitudes are much more dominant than the negative ones.

Adapted primary literature readers' attitudes toward different learning styles are shown in Figure 5B. The analysis was based on three statements: "I would like to learn more subjects using articles"; "I would rather study using a textbook" and "I prefer that the teacher explain, so I won't have to read by myself" (items 7, 8, and 9 in part D of the questionnaire, see Appendix B). Note that students' preferred learning styles change gradually, in correlation with their increase in age and prior knowledge (Figure 5B). While the importance of the teacher as a source of information decreases ($r = -.73$, $p = .017$), the willingness to learn using articles increases ($r = .69$, $p = .028$). The readiness to learn from textbooks remains quite constant among the knowledge groups, except for the LK tenth-graders who demonstrate a more positive attitude toward this way of learning than the others ($r = -.63$, $p = .05$). The teacher's importance as a source of knowledge appears to decrease with an increase in the students' ability to learn by themselves using adapted primary literature.

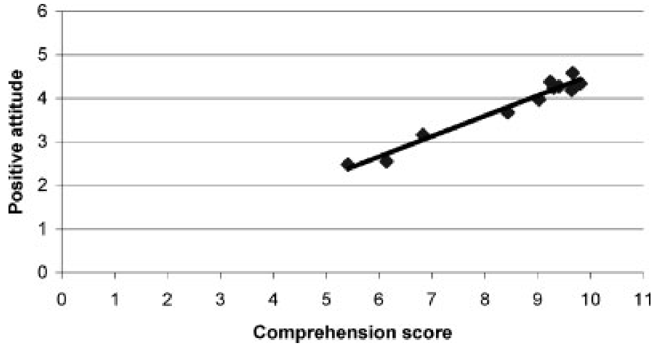

Figure 6. Correlation between average class comprehension score and students' attitudes towards the task. High-school biology students that were tested for their reading comprehension (comprehension score) responded to a series of 11 statements about the reading task, 4 of them positive in nature. Students were asked to grade those statements on a Likert-type scale from 1–6 (1 = strongly disagree, 6 = strongly agree). Each dot represents one class's average score on both axes, $r = 0.98$, $p < 0.0001$.

We found a strong correlation between classes' average scores in the comprehension section of the questionnaire and their average positive attitudes toward the task (Figure 6). The correlation was stronger with the positive attitudes than with the negative ones ($r = .98$, $r = -.85$, respectively). Correlation of positive and negative attitudes with the scientific inquiry scores were a little weaker ($r = .74$, $r = -.73$, respectively), but still very obvious. These findings suggest that the task strictly measured the students' abilities and motivations, regardless of their teachers' mode of instruction.

Discussion

In this study we compared four groups of subjects, each with differing degrees of prior knowledge in biology, who had read a domain-related text written in either the scientific research article genre (adapted primary literature) or the popular-scientific genre (secondary literature). Although there was no significant difference in the students' ability to summarize the main ideas of each text, indicating no eminent distinction in their content, we found that students who read adapted primary literature demonstrated better inquiry skills, whereas secondary literature readers performed better on the comprehension section of the test.

Since the scientific content of the two texts was for the most part identical, we suggest that the differences in students' performances stem from the structure of the text, dictated by its genre. The orderly way in which the theoretical background gives birth to the research hypothesis, the research hypothesis controls the selection of the methods, the methods determine the nature of the results that are obtained in the experiment, the results serve as raw material for the discussion, and the discussion usually yields ideas for future hypotheses, helps the student follow the experiment's internal logic as it unfolds. This internal logic, embedded in the primary literature genre, is not apparent to the student who reads secondary literature, in which the original sequence of the work is omitted for the sake of raising readers' interest.

Our results agree with Epstein's (1970) report of a biology course that was based on learning from a set of research papers which reopened the 17-year-old students' stores of curiosity about how science is done and what a biologist does when he or she is doing biology, with Muench's (2000) statement regarding the unique potential of primary literature to instruct students on the nature of scientific reasoning and communication, and with Schulte's (2003) observation that the similarity in structure of the scientific method and scientific writing can facilitate the understanding of each.

While adapted primary literature has an advantage in conveying knowledge concerning the syntactic structure of the discipline (Schwab, 1978; Shulman, 1986), secondary literature's lack of permissiveness for information gaps (compared with adapted primary literature), permits the students to better understand the article's content. Its greater explanatory coherence allows a better understanding, even for students who lack some of the prior knowledge required (McNamara, Kintsch, Songer, & Kintsch, 1996).

Another possible reason for the tendency of adapted primary literature readers to raise more scientific criticism of the researchers' work might be an outcome of the different source of authority in the two texts. Readers of the popular-scientific article learn of the important progression in the struggle against anthrax that was achieved by a group of scientists from Harvard, while readers of the research article learn about the same breakthrough in a much humbler way. The journal's name is totally unfamiliar to the students, and the work is presented in a scientific genre, which is usually underestimated and modest. Without the press acting as a mediator, the research and its contractors may seem less impressive to nonprofessional readers and be more vulnerable to criticism. The writer of the popular-scientific article equips the readers with the external criteria (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) they are missing, by which they are able to evaluate the work and put it in its proper perspective. Since the significance of the work that is presented to the students is highly impressive, students may be more intimidated by the idea of criticizing it, as expressed in an answer given by a LK tenth-grader who had read the secondary literature text: "They are the researchers, so I can't have any criticism about their work. They are the ones who know because they are scientists."

The two items in which adapted primary literature readers outperformed the secondary literature readers have another unique characteristic in common: in both, heterogeneity within the knowledge group increased with prior knowledge and grade, whereas in all other tasks homogeneity within the knowledge group grew with prior knowledge and grade. These two items were harder for the students to complete, as can be confirmed by comparison of their relative scores, and for that reason heterogeneity was greater among biology majors.

It is interesting to note that although the demands for suggestions of future investigations and for another application in the scientific inquiry section were rather similar, there was a difference between them regarding average scores and text genre-related performances. Since students are quite familiar with the demand for planning the next step of an experiment from their lab experience, they found it easier to complete and no advantage was observed in using adapted primary literature. However, when the task was new to the students, as with the application item, they used the adapted primary literature's unique structure as some sort of a theoretical organizer. In research articles, abstracts usually precede the text itself and thus may act as an organizer of its content (Ausubel, 1963). Similarly, the adapted primary literature's structure, due to the similarity in the structure of scientific writing and scientific method, might serve as an organizer for students' scientific thinking.

The secondary literature readers' tendency to offer more detailed ideas for future investigation was not significant, but was repeated in all four prior-knowledge groups. This anomaly surprised us, and at present we do not understand its origin.

Irrespective of their differences, both adapted primary and secondary texts describe a case study of a current issue. Because of their ability to communicate scientific ideas in a way that makes them memorable and meaningful, they can both be characterized as "explanatory stories" (King, 2002; Millar & Osborne, 1998; Millar, Osborne, & Nott, 1998). Between the lines of the original research article, one can read a hair-raising tale of a world inhabited by heroes and villains: the inhibitor and the anthrax toxin. Both are present in the adapted versions as well. The heroes and the villains appear both at the microscopic level (the inhibitor and the anthrax toxin) and at the macroscopic level (the researchers and the terrorists). Since the macroscopic level is sadly relevant to the students' lives, who fulfill the damsel-in-distress role, they are more motivated to understand the microscopic level as well.

Regardless of the type of literature they read, students showed an increase in their summarization abilities, reading comprehension, inference abilities and inquiry skills with increased prior knowledge in biology. This result agrees well with Chi, Feltovich and Glaser's research on novices and experts (1981). Their work pointed to the importance of the knowledge base as a means of success in problem-solving, due to the different ways in which novices and experts perceive the problems, categorize them, and use their knowledge in order to solve the problems (Chi, Feltovich, & Glaser, 1981). The improvement in achievements, which was correlated with an increase in prior knowledge, might also be explained by findings, which showed that the self-explanations of students with sound vs. low prior-knowledge differs in the extent of using prior knowledge, closely following the given example, and the use of abstract vs. concrete terms (Sandmann, Mackensen, & Lind, 2002).

While understanding stories usually requires causal knowledge about people's motivations, goals and actions (Moravcsik & Kintsch, 1993), reading an account of scientific research requires specific prior knowledge concerning the scientific enterprise, concepts, language, and patterns of argumentation in order to understand it (Yore, Craig, & Maguire, 1998). For example, it was found that limited topic or domain knowledge can have a significant negative impact on students' understanding of a physics text (Alexander & Kulikowich, 1994). Individuals with prior knowledge may process domain-related information differently than those lacking this knowledge. Knowledge differences among the various groups were prominent in the results obtained from all the assessment tools, but they were most notable in the processing of statements that required inference abilities and in the scientific inquiry items. Those questions called for higher cognitive abilities as well as for prior knowledge that was not explicit in the text. Text coherence may play a secondary role in comprehension when knowledge allows for the development of a more enriched conceptual representation of the text at hand (Fincher-Kiefer, 1992).

However, not only factual prior knowledge distinguishes seniors from freshmen. While seniors are highly trained in bringing up testable hypotheses and designing investigations with dependent and independent variables, freshmen are only taking their first steps in the school lab. Skilled evaluation, for example, requires, among other things, knowledge about features of the research that are correlated with its quality, such as scientific methodology, e.g., use of control groups and adequate sample sizes (Korpan, Bisanz, Bisanz, & Henderson, 1997). Knowledge of those features and patterns of the experimental research is more abundant as one spends more years learning science, and this may be why a Duncan grouping test of the different prior knowledge groups' performances for this question indicated a separate characteristic for eleventh- and twelfth-graders, while the HK and LK tenth-graders remained together.

Although there were no significant differences between male and female students' high school biology grades, female students outperformed their male classmates with respect to abstract writing and comprehension. Since the task was text-based in nature, one might assume these differences in achievements stem from gender-related differences in reading ability. However, the reading abilities of Israeli elementary school students were reported to be equally high for both sexes (Gross, 1978) and only small gender differences were reported with regard to American high school students' reading achievements (Hogrebe, Nist, & Newman, 1985). Our results are compatible with those obtained from the biology matriculation exams taking place in Israel during 2002, in which the average grade for the males ($n = 3{,}500$) was 80.8 and 83.8 for the females

($n = 6{,}668$), out of a maximum score of 100 [according to B. Agrest, Chief Inspector of Biology Education in Israel (personal communication, October 23, 2002)].

Empirical data show that for readers with a low level of background knowledge, a text should be as coherent and explicit as possible, while for readers with adequate background knowledge, texts with coherence gaps that stimulate constructive activities are in fact better for learning (McNamara et al., 1996). Following this rationale, groups of readers may be characterized by their knowledge and skills, to help define a set of texts that can serve as the basis for successful learning (Kintsch, 1994). Our results showed a different pattern: students with various amounts of prior knowledge demonstrated better comprehension after reading a coherent and explicit text than after reading a less coherent text. Thus, it seems to us that different text genres promote different educational goals.

This result agrees with Wignell's (1994) findings that applied science and humanities textbooks for junior secondary education in Australia employ a different selection of genres (as demonstrated by using an action-oriented or information-oriented scale), because the curriculum areas themselves have different purposes. Science textbooks are the dominant influences behind most secondary science instruction (Yore, 1991). However, a variety of learning materials written in different genres can be used in science class. Wellington (1991) suggests that science presented in newspapers can be of value in formal science education if used carefully and critically. Incidentally, a great many teachers in Northern Ireland use newspapers to support science instruction in order to highlight the link between school science and everyday life and thus to stimulate interest (Jarman & McClune, 2001, 2002). Norris and Phillips (1994), in contrast, found that even top science students at the twelfth grade did not fully grasp the fundamentals of interpreting popular reports of science: fewer than half of the students interpreted correctly statements that required a semantic or logical connection to other statements, and surprisingly, they attributed to the statements a higher degree of certainty than was expressed by the authors.

Another alternative text that is being used in the science classroom is that of trade books. Fisher (1980) found that the use of literature as a method of teaching science concepts stimulated talk outside class about science, and made students feel that science is a part of their lives. These resulting feelings can be a motivating factor in retaining learning and encouraging further independent study. In a research study conducted among 232 disadvantaged seventh-graders, it was found that texts written either in scientific prose or in a narrative style did not induce appreciable differences in the students' knowledge of the major scientific elements contained in the texts. However, when asked for their opinion, an overwhelming majority of the students preferred the narrative version of the text (Rosenblum & Markovits, 1976). In contrast, Guzzetti, Williams, Skeels, and Wu (1997) state that the inclusion of narrative structures is unnecessary at the secondary level.

Refutational text and conceptual change text, which address common misconceptions as well as scientific explanations, are another alternative to the traditional textbook. Both were shown to be effective for inducing conceptual change in science learning (Chambers & Andre, 1997; Guzzetti et al., 1997; Hynd, McWhorter, Phares, & Suttles, 1994).

Considering all these examples, we suggest that a set of texts in different genres can be defined in order to enhance different intended learning outcomes.

Implications

Although the study described above sheds some light on the advantages of using adapted primary and secondary literatures, caution is needed in identifying any implications for high school biology education, as discussed below. The lack of establishment of construct and content validity and the sole reliance on expert examination of the instrument is one limitation of the study. Furthermore, we recognize that the results were not yet duplicated by a reciprocal experiment or using different set of primary and secondary texts, and plan to replicate and widen the research to include more text genres in the future. Another point to be made is the deliberate removal of the teachers' input from the experiment, while it is clear that in practice the texts will be mediated to the students by their biology teacher using various teaching strategies.

Keeping the study's limitations in mind, the results may have several educational implications. The use of adapted primary and secondary literature in high school biology classes yielded encouraging results among biology majors according to all of the assessment tools used and from a gender-equity perspective. Biology majors expressed much more dominant positive attitudes than negative ones toward the reading task and gave a high rating to the idea of studying more issues using articles (data concerning secondary literature readers was not shown). The use of adapted primary and secondary literature in high school science classes may enrich the variety of instructional strategies with challenging and up-to-date learning materials. The female students' higher ability to summarize and comprehend the texts may call for teaching strategies that include heterogeneous teamwork.

However, three clear differences were found between the results obtained through the use of adapted primary versus secondary literature in high school biology classes: adapted primary literature creates a better understanding of the nature of scientific inquiry, while secondary literature permits better comprehension of the content and creates less negative attitudes among the students. The consequences of text genre selection for high school science teaching should not be overlooked. One of the aims of the science curriculum is the development of will and ability to read and understand newspaper science with healthy skepticism (Wellington, 1991) and to equip the student with the skills needed for sustaining independent and lifelong learning (Bettencourt, 1989; Hurd, 1985). To achieve those goals, students' attitudes toward self-directed secondary literature reading are of the utmost importance. Students' attitudes, as they were demonstrated in this work, were significantly more negative toward adapted primary literature reading than toward secondary literature. These attitudes might have an affect on the future citizens' will to read updated scientific literature later in their lives and should be considered very seriously. In contrast, it seems that of the two text genres, the adapted primary literature equips the student with a variety of tools and skills that a future citizen and decision-maker should possess.

Thus, we are faced with a hard choice between two desirable educational goals. We propose to avoid the dilemma by having the best of both worlds: present high school students with adapted primary literature that is suited to their cognitive level in order to enhance their understanding of the nature of scientific inquiry, but wrap it in a secondary literature package of popular-scientific articles about the same topic. The secondary literature articles may fill some of the information gaps, allowing a better understanding for students who lack parts of the prior knowledge required; equip the readers with the external criteria they are missing, by which they can evaluate the works' significance; and, it is hoped, improve students' attitude toward self-directed secondary literature reading in the future. In this exemplary framework, adapted primary and secondary literature interact together to create a well-informed future citizenry.

The authors thank Mrs. Yetty Varon for her expert statistical analysis and support during the performance of this research. We also thank the teachers and students who participated in the experiment.

Appendix A

Congruent paragraphs from the original article and both adapted texts are presented.

Original Primary Literature

We synthesized a derivative of polyacrylamide that had multiple, covalently linked copies of the P1 peptide. This polymer (polyvalent inhibitor, or PVI) contained, on average, 22 peptide units and ~900 acrylamide monomers per molecule (Mourez et al., 2001).

Adapted Primary Literature

Inhibitor design: A molecule was constructed from many copies of the peptide that were attached to each other by a synthetic material that served as a flexible backbone. On average, there were 22 peptides in every molecule.

Secondary Literature

However, minor disturbance to the toxin's assembly won't save people from death. An effective medication should intensely interfere or even completely prevent the assembly of the toxin. Therefore, the researchers developed an inhibitor, constructed from 22 copies of the peptide, attached to synthetic material that served as a flexible backbone for the molecule.

Appendix B

Questionnaire

A. Briefly summarize the main points of the article.
B. Indicate true or false for each of the statements and provide an explanation:

1. Antibiotics do not have any influence on the anthrax bacteria, and for that reason it is important to develop an inhibitor to the toxin.
2. The toxin is constructed of 22 copies of the protein PA.
3. The inhibitor interferes with the third stage of the toxin assembly, as described in Figure 1.
4. The inhibitor is being investigated because it will be the basis for the development of a drug for anthrax.
5. The researchers added the diphtheria toxin to the cell culture because it is easy to tell if it has entered the cell.
6. A single peptide can serve as a better medicine than the inhibitor, because it binds more strongly with PA.
7. The fact that the inhibitor prevented intoxication, even when it was administered 3–4 minutes after the toxin, has practical significance.
8. Rats injected with a high dosage of inhibitor suffered from side effects.
9. The researchers wanted to find a peptide that would specifically bind the truncated PA and not the whole protein, in order to increase the medicine's effectiveness.
10. The fact that the peptide disrupted the binding of the enzyme LF to PA, supports the assumption that they bind to it at the same place.
11. After the researchers showed that the inhibitor prevents intoxication in cell culture, there was actually no point to the experiment with the rats.

C. Open questions:

1. Which experiments would you conduct now in order to further test the medicine's efficiency?
2. Do you have any scientific criticism of the researchers' work? Are there any experiments that you would have conducted differently?
3. Can you think of any other applications for the technique that was used by the researchers to develop the inhibitor?

D. Attitude questionnaire:

1. I enjoyed reading the article
2. The article was difficult to read
3. The article was difficult to comprehend
4. The article was interesting
5. The article was frustrating
6. I would like to know more about the article's subject
7. I would like to learn more subjects using articles
8. I would rather study using a textbook
9. I prefer that the teacher explain, so I won't have to read by myself
10. The methods don't interest me and they can be skipped in the next articles
11. The article was too long

Other remarks concerning the learning style and the article.

Appendix C

Duncan grouping test for the five tenth-grade biology classes

Class	N	Mean[a,b]	Std	Duncan Grouping
1	25	22.76	3.1	A
2	24	21.04	4.6	A
3	21	15.24	3.9	B
4	31	13.97	6.2	B
5	29	12.52	6.1	B

[a]$F(4,125) = 21.05$ ($p = .0001$).
[b]Maximum score of 36 was calculated for the comprehension and inquiry skills sections.

Appendix D

Duncan grouping test for the inquiry skills section among the four prior knowledge groups

		Future Investigation			Critical Thinking			Application		
Prior knowledge group	N	Mean	Std	Duncan Grouping	Mean	Std	Duncan Grouping	Mean	Std	Duncan Grouping
12th grade	27	4.33	1.07	A	2.00	1.62	A	3.26	1.43	A
11th grade	115	3.62	1.38	B	0.84	1.50	B	2.26	1.36	B
HK 10th grade	49	2.31	1.70	C	0.20	0.82	C	1.29	1.22	C
LK 10th grade	81	1.01	1.45	D	0.19	0.78	C	0.46	1.82	D
F(3,268)		65.56****			17.8****			53.55****		

****$p < 0.0001$.

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