Testing Students' Ability to Read Scientific English

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Context of the Problem

In 1967, Selinker and his colleagues at the University of Washington undertook a project in conjunction with the Department of Engineering to teach scientific English to foreign students. Within a short time, the linguists found that their approach to teaching of scientific English via vocabulary study and syntax was not working. While the students understood all the words in each sentence and all of the sentences that make up the discourse, they seemed unable to comprehend the total meaning of the passage. As the researchers later described the problem, the students were "fossilizing" their approach toward scientific reading by realizing only the explicit aspects of a passage rather than comprehending an implicit level that operates in complex scientific writing.

Selinker and his colleagues claim that in scientific materials, rhetoric and grammatical choices are related in subtle ways. The choice of tenses, for example, is dependent not on "time lines", but on the attitude of the technical writer toward the events or materials which he or she is describing:

> *Suppose the technical author is attempting to write up an experiment. Reference to the time of the events or states is of little help in understanding tense usage since, from the point of view of the technical author, nearly everything he is writing about is a past event or state in relation to the point in time in which he is writing the report. The work of other investigators he mentions is finished, his own work is finished, and his conclusions have probably all been arrived at. Yet, importantly, his writing does not restrict itself to the past tense, but shows considerable variety in tense usage. This variety must be due to other than time factors relative to the act of writing. (1974, p. 86)*

Based on their analysis of scientific articles, Selinker et al. claim that certain tenses are commonly used for certain rhetorical functions. For example, the tense chosen by the writer to describe apparatus used in an experiment is either in the past or present tense depending on the "history of use" of the apparatus. If the apparatus has been solely devised for the experiment that is being reported, its description will normally be in the past tense. If, however, the apparatus is of an established pattern or design which exists and is used for purposes other than the experiment reported, its description will normally be in the present tense.

Past research is presented in both the present perfect and past tenses; the present perfect tense indicates that the research in question is directly related to the work at hand while the past tense is used when the past research seems to be less directly related to the present work, and it is included more as historical background.

Assuming the above claims about the rhetorical functions of tense in technical discourse to be true, how do they affect the comprehension of foreign readers (and the intelligibility of foreign writers) for whom these rhetorical functions may differ from those in their native languages?

Purpose of the Study

The purpose of this study is to test the awareness of three groups of subjects (native non-science, native science, and non-native science students) to the rhetorical functions of tense in technical discourse, the pattern suggested by Selinker et al. Specifically, answers were sought to the following research questions:

1. Does the performance of native non-science and native science students support the claims made by Selinker et al. (that tense involves categories other than time relations.)?

2. Do non-native science students show an awareness of the rhetorical functions of tense in their reading of technical discourse?

Review of Literature

English for Science and Technology, or, as it is sometimes called, Scientific English, is of interest to ESL teachers and materials developers as an important variety of written English. The traditional approaches to its study in an ESL context have included vocabulary exercises and grammar drills on structures most commonly found in written scientific English. A possible problem with these approaches is that they may "condemn the students to work with isolated sentences divorced from context and, very often, from content as well" (Lackstrom et al., 1970). This situation has probably developed from American preoccupation with language teaching for oral communication. But, whatever the cause, the crucial roles of subject matter and rhetoric have been neglected by teachers and often ignored in the literature as well.

Not until recently has some attention been paid to the units beyond the level of the sentence. Kaplan (1972), for example, comments that "rhetorical frames may have greater importance in developing linguistic proficiency than the isolated grammatical frames which constitute the largest part of second language teaching" (p. x). Language is the "constant state of agitated interactions" (p. 28), which cannot best be described by division. Others, including Horn (1969), and Arapoff (1970) suggest that students be trained in the perception and use of those signals which alert the skilled reader (and skilled writer) to connections, relations, contrasts, changes of directions and exemplifications. Strevens (1973) and Bartolic (1975) propose the same general approach to the teaching of scientific English.

It is true that the knowledge of the explicit nature of rhetorical transitions suggested above can be of inestimable value to science students. However, as Selinker et al. (1972, 1974, 1976) point out, much of the rhetorical information in scientific English discourse is often implicit rather than explicit. It is this implicit information that causes the most trouble to non-native students of English. For example, scientific English relies heavily upon the "presupposition" that the use of a certain tense in the discourse signals a change in rhetorical function. Consider the following examples:

1. The technique used is.....
2. The technique used was.....

Whereas sentence 1 will outline a technique that can be used repeatedly to achieve the same results, sentence 2 merely states the conditions for a particular experiment. Another example:

3. Brown and Smith have reported.....
4. Brown and Smith reported.....

Both discuss previous research but in sentence 3 Brown and Smith's work is valued as more relevant to the research at hand or as still generally true whereas sentence 4 seems to refer to a single, specific incident.

Inspired by Selinker et al. work, Wilkins (1977) constructed a test of scientific English, using as subjects three groups: 1) native English-speaking non-science (i.e. ESL) students, 2) native English-speaking science students, 3) non-native English-speaking science students. The results of the test tended to support Selinker's claim that an effective reading of scientific English prose requires a knowledge of the discourse functions of verbal elements. The results also supported Wilkins' hypothesis that experience in reading scientific English endows the students with a competence significantly different from the reading competence of a native English speaker without scientific experience.

This study attempts to deal with the two areas not covered in Wilkins' study: the choice of tenses in describing an experimental apparatus, and the choice of tenses in describing the degree of relevance found in the reports of past research.

The Study

Method

Subjects : There were 102 subjects: 51 non-native undergraduate and graduate UCLA science students, 33 native undergraduate and graduate UCLA science students and 18 native graduate students in a training course for ESL teachers.

Non-natives: These subjects came from a variety of scientific fields: Computer Science (17), Engineering (15), Physics (4), Mathematics (5), Biology (3), Biochemistry (2), Life Sciences (2), Medicine (1), Kinesiology (1), and Environmental Health Science (1). Most of these students are considered to be linguistically "advanced". They have either completed the ESL service courses or have been exempted from the ESL requirement. The time each had been studying in the U.S. ranged from three months to seven years. A variety of native languages were spoken by these subjects: Korean (12), Persian (10), Arabic (10), Chinese (6), Japanese (4), Thai (3), Armenian (2), Vietnamese (2), French (1) and Russian (1).

Natives: 18 of the native speakers were graduate students in a training course for ESL teachers. The other 33 were from various scientific fields: Engineering (11), Computer Science (9), Biology (6), Chemistry (6), Biochemistry (3), Physics (3), Kinesiology (2), Pharmacy (1), and Mathematics (1)

Materials: A short multiple-choice test consisting of two items was constructed from the scientific articles used in the study of Selinker et al (1972). Each of the items was aimed at testing the following notions:

Item #1 : the choice of tense forms in sentences relating to the temporariness or permanence of a piece of scientific apparatus: *past* for temporary; *present* for permanent.

Item #2 : the choice of tense forms in sentences describing the degree of present relevance found in the reports of past research: *present perfect* for more relevant; *past* for less relevant.

For item #1, two reading passages (A and B) describing two different kinds of apparatus were given. The first reading was in past tense; the second, in present tense. Then there were three possible choices, one of which was based on the hypothesis of Selinker et al.

For item #2, there were two readings (A and B) describing the state of past research related to the experiment at hand. The first reading was in past tense; the second, in present perfect. Then there were three possible choices, one of which was based on the hypothesis of Selinker et al.

For each of the above items, the subjects were asked to identify (if they could do so) the clues they used in arriving at the answers. Such information is then used to determine whether the clues are the ones Selinker et al. say are crucial.

Three forms of the test were constructed, using the same grammatical structures, but different content: Form I, Form II, From III. For complete test forms, see Appendix.

Procedure : The subjects were divided into 3 groups, each consisting of 17 non-natives and 17 natives (11 science students and 6 students in a training course for ESL teachers). Each group was then assigned to do one of the three forms of the test.

All subjects, with the exception of the students in a training course for ESL teachers, took the test in the presence of the examiner. Although dictionaries were made available and it was stressed that their use was permitted, few students referred to them.

The Result

The following tables present the number and percent of the subjects' responses to the test.

Table 1

Responses of Native and Non-Native Speakers to Item #1 Form I

Types of Subjects		Three possible choices		
		a	b	c
17 Natives	No.	14	1	2
	%	82.35	5.88	11.76
17 Non-Natives	No	9	4	4
	%	52.94	23.52	23.52

Table 2

Responses of Native and Non-Native Speakers to Item #2 Form I

Types of Subjects		Three possible choices		
		a	b	c
17 Natives	No.	2	14	1
	%	11.76	82.35	5.88
17 Non-Natives	No.	4	9	4
	%	23.52	52.94	23.52

Table 3

Responses of Native and Non-Native Speakers to Item #1 From II

Types of Subjects		Three possible choices		
		a	b	a
17 Natives	No.	17	0	0
	%	100	0	0
17 Non-Natives	No.	8	4	5
	%	47.05	23.52	29.41

Table 4

Responses of Native and Non-Native Speakers to Item #2 Form II

Types of Subjects		Three possible choices		
		a	b	c
17 Natives	No.	2	10	5
	%	11.76	58.82	29.41
17 Non-Natives	No.	6	4	7
	%	35.29	23.52	41.17

Table 5

Responses of Native and Non-Native Speaker to Item #1 Form III

Types of Subjects		Three possible choices		
		a	b	c
17 Natives	No.	13	1	3
	%	76.47	5.88	17.64
17 Non-Natives	No.	7	4	6
	%	41.17	23.52	35.29

Table 6

Responses of Native and Non-Native Speakers to Item #2 From III

Types of Subjects		Three possible choices		
		a	b	c
17 Natives	No.	4	7	6
	%	23.52	41.17	35.29
17 Non-Native	No.	5	6	6
	%	29.41	35.29	35.29

Of the combined total of 51 native speakers doing the three forms of the test, 44 (86.27 %) chose the predicted answer for item # 1. Some of the explanations that accompanied their choices supported the claim of Selinker et al. about the choice of tense forms in sentences relating to the temporariness or permanence of a piece of apparatus (past tense vs. present tense). However, they also revealed that quite a large number of these subjects used other clues, different from the ones Selinker identifies as crucial.

Of the same 51 native speakers, 31 (60.78 %) chose the predicted answer for item # 2. Selinker's claim that there are semantic variables for the allocation of the past or present perfect to a discussion of past research seems not to have been strongly in this study. Most of the clue explanations given by the subjects seem to suggest that to make such a semantic distinction, one cannot depend solely on the linguistic message. Other extralinguistic factors, such as the writer's attitude and the reader's familairity with the subject matter, have to be taken into consideration as well.

Among the total of 51 non-native science students doing the three forms of the test, 24 (47.05 %) chose the predicted answer for item # 1 ; 19 (37.25 %) chose the predicted answer for item # 2. However, it is not valid to conclude from these results that the students were aware of the rhetorical impact of tenses suggested by Selinker et al. As in the case of the native speakers, non-native science students often used clues different from the ones Selinker et al. say are important. Also, since most of these students did not give any explanations about their choices, it is difficult to decide whether they did use the clues suggested by Selinker et al. or whether they merely guessed at the answers. On the other hand, quite a large number of these students failed to choose the correct answers. This seems to indicate that most non-native science students in this study were not aware of the rhetorical functions of tense in scientific materials.

Implications for Teaching Writing

As Selinker et al. (1974) point out, non-native science students often fail to communicate their intended message through not observing distinctions that technical writers make, for example, with reference to verb choices of the types tested in this study (i.e. "The technique used is... vs. The technique used was...", "Brown and Smith have reported... vs. Brown and Smith reported..."). Possibly this is because students have been taught that tenses are chosen according to criteria related to time. The student in attempting to write a laboratory report, for example, knows that everything happened in the past with regard to the moment of writing and often puts all his tenses in the past. He thus fails to observe the considerable variety of tense usage that occurs in authentic technical writing. This procedure on the part of non-native speakers often results in a lack of coherence in their writing : the students produce grammatically correct sentences which are "errors" in the sense that they are inconsistent in context and do not always express the intended meaning.

The following procedure has been suggested by Selinker et al. as an example of how such problems can be handled in a class situation. Suppose the teaching unit is to show tense usage in respect to past research. The teacher begins with class discussion on the rhetorical and rhetorical-grammatical principles involved. These are illustrated by the presentation and analysis of genuine sample materials taken from current technical writing. The student is then asked to read and analyse sample materials which the teacher provides. Next, the student is asked to locate equivalent materials in the books or articles he is reading for his technical courses. In this way, the teacher tries to teach principles that occur in the student's own reading. Next the teacher asks the student to apply those rhetorical techniques in a writing assignment with a particular purpose, for example, describing past research. Direct feedback on this assignment consists of error analysis in class which relates grammatical errors to inappropriately presented rhetorical techniques.

Implications for Teaching Reading

The fact that the subjects in this study used different kinds of clues in order to get to the answers suggests that there are many variables involved in reading comprehension. Tense usage is one of these many. In teaching technical reading to non-native speakers of English, emphasis should be given to training them to be aware not only of the rhetorical functions of tense suggested by Selinker et al., but of other contextual clues as well.

As a first step in such training, care should be taken to incorporate language clues such as those cited by the subjects in this study (i.e. the titles, the dates, modals, and tenses) into a reading lesson. This can be done by manufacturing texts which rely only on the distinctions of the clues. Using such texts, the teacher can lead students to look for various types of clues, one clue at a time. As the course develops, reinforcement is done by giving students authentic EST materials (e.g. articles from a scientific journal) to identify all the language clues already covered in class.

Suggestions for Further Research

The results of this study raise many questions which should lead to further areas of research. The most apparent and important question is whether the format of the experimental design provides a valid means of testing the hypotheses of Selinker et al. This format is based on a rather large assumption, that measuring ability to choose the correct description for given passages is a true measure of one's awareness of the rhetorical functions of tense. As the results of the study turned out, there were many variables operating in reading comprehension. Also, many subjects, especially the large number of those who did not give any clue explanations, may have got the correct answers simply by guessing. A more effective method of testing the hypotheses of Selinker et al. is to include more than one type of test, for example, cloze passages and editing-type test.

A second question is whether it is appropriate to use almost exclusively science-oriented native speakers to test the validity of Selinker's claims. Would the results have better supported his claims if a larger number of linguistically sophisticated native speakers (e.g. students majoring in linguistics or training to be English language teachers) had been included in the study ?

A third question is whether the non-natives' levels of language proficiency as well as their academic levels and previous training play important roles in this kind of test. A suggestion for further research would be to compare the performance between two groups of subjects, for example, non-native science students with the same academic levels but different levels of language proficiency.

The results of any of the studies proposed above could be compared with the results of this study, and used to provide further documentation of the need for teaching grammatical choices in relation to the functions of rhetorical units.

Appendix

Form I

Reading Test of Scientific English

This is a test of how well you can read and understand scientific English. The samples were taken from a scientific journal.

For Non-Native Speakers of English

1. Native language_____
2. Academic field_____
   Undergraduate_____
   Graduate_____
3. How long have you been studying in the U.S. ?_____
4. Are you now enrolled English 33 A ?_____
   English 33 B ?_____
   English 33 C ?_____

   or

   Have you already completed English 33 A ?_____
   English 33 B ?_____
   English 33 C ?_____

   or

   Have you been exempted from taking the above courses ?_____

For Native Speakers of English

Academic field_____
Undergraduate_____
Graduate_____

Instructions : 1. Read both of the following passages
2. Circle the statements (*a*, *b*, or c) that best describes the passages
3. Identify the clues (i.e. bits of information from the passages) you used in arriving at the answer

Passage A :

The test section was constructed of the pure copper cylinder 2 ft. long, 6 in. id and 6.25 in. od. Both ends of the cylinder were closed with removable Pyrex-glass end plates 1/4 in. thick. A fluid part was located at each end of the cylinder.

Passage B :

The measurements were made on the sidewall of the Trisonic One-Foot-Tunnel of the Douglas Aerophysics Laboratory. The tunnel is a blowdown-to-atmosphere facility operating over the Mach number range 0.2 to 3.5. Mach number in the tunnel is generated by fixed nozzle blocks at supersonic speeds. Speeds in the subsonic and transonic range are controlled by changing the area of a second throat down-stream of the test section.

Please circle either *a*, *b*, or *c*,

a. *Passage A* describes an apparatus designed for a specific experiment; *passage B* describes an existing apparatus that has been used in, but not specifically designed for, that experiment.

b. *Passage A* describes an existing apparatus that has been used in, but not specifically designed for, that experiment; *passage B* describes an apparatus designed for a specific experiment.

c. Both *passage A* and *passage B* describe an apparatus designed for a specific experiment.

Clues used :

The following are taken from two introductory paragraphs of an article entitled *Binaural Masking of a Tone by a Tone Plus Noise*. Both describe the state of past research related to the experiment presented in the paper.

Instruction : 1. Read both of the following paragraph fragments
2. Circle the statement (*a*, *b*, or *c*) that best describes the paragraph fragments given
3. Identify the clues (bits of information from the paragraphs) you used in arriving at the answer

A. Hirsh and Webster (1964) reported that they found no change in the masked threshold of a tone signal when the interaural differences were changed.

B. Jeffress et al. (1972) have recently shown, however, that the masking level differences (MLDS) are found if the signal duration is made less than approximately 100 msec.

Please circle either *a*, *b*, or *c*.

a. The past research described in *A* is more directly related–in terms of importance–to the experiment at hand than the past research described in *B*.

b. The past research described in *B* is more directly related–in terms of importance–to the experiment at hand than the past research described in *A*.

c. The past research described in *A* and *B* are both equally important to the experiment at hand.

Clues used :

Form II

Reading Test of Scientific English

This is a test of how well you can read and understand scientific English. The samples were taken from a scientific journal.

For Non-Native Speakers of English

1. Native language_____
2. Academic field_____
   Undergraduate_____
   Graduate_____
3. How long have you been studying in the U.S. ?_____
4. Are you now enrolled in English 33 A ?_____
   English 33 B ?_____
   English 33 C?_____

   or

   Have you already completed English 33 A ?_____
   English 33 B ?_____
   English 33 C ? _____

   or

   Have you been exempted from taking the above course ?_____

For Native Speakers of English

Academic field_____
Undergraduate_____
Graduate_____

Instructions : 1. Read both of the following passages
2. Circle the statement (*a*, *b*, or *c*) that best describes the passages
3. Identify the clues (i.e. bits of information from the passages) you used in arriving at the answer

Passage A :

The Picosecond laser apparatus was constructed using a double beam I and I_0. The output signal was detected with an optical multichannel analyzer (SSR Instruments) which was coupled with a minicomputer for data reduction and averaging. A photodiode (ITT E 4000) monitored the 530-nm photolysis pulse. The double beam permitted accurate adjustment for short-to-short variations of the laser and the continuum probing pulse.

Passage B :

The Bell diamond pressure cell was used to test the hypothesis suggested. The apparatus consists of two single-crystal diamonds opposed as pressure anvils. A scissors-shaped lever-block assembly is spring-loaded to apply a mechanical advantage of 2. The diamonds are supported by half-cylinder seats of tungsten carbide with a zinconium shim (0.0001 in. thick) placed between the low-pressure-bearing surface.

Please circle either *a*, *b*, or *c* :

a. *Passage A* describes an apparatus designed for a specific experiment : *passage B* describes an existing apparatus that has been used in, but not specifically designed for, that experiment.
b. *Passage A* describes an existing apparatus that has been used in, but not specifically designed for that experiment ; *passage B* describes an apparatus designed for a specific experiment.
c. Both *passage A* and *passage B* describe an apparatus designed for a specific experiment.

Clues used :

The following are taken from two introductory paragraphs of an article entitled *Specific Immune Tolerance to Egg Albumin Induced in the Guinea Pig by Gyclophoshoramide.* Both describe the state of past research related to the experiment in the paper.

Instructions : 1. Read both of the following paragraph fragmentes
2. Circle the statement (*a*, *b*, or *c*) that best describes the paragraph fragments given
3. Identify the clues (bits of information from the paragraphs) you used in arriving at the answer

A. Schwartz and Dameshek (1969) reported that treatment of rabbits with 6-Mercatopurine could induce a specific immune tolerance to human albumin.

B. Maguire et al. (1974) have recently shown that an alkylating agent, cyclophosphoramide, may inhibit primary sensitization and produce specific tolerance to egg-induced systemic anaphylaxis in the guinea pig.

Please circle either *a*, *b*, or *c*:

a. The past research described in *A* is more directly related–in terms of importance–to the experiment at hand than the past research described in *B*.

b. The past research described in *B* is more directly related–in terms of importance–to the experiment at hand than the past research described in A.

c. The past research described in *A* and *B* are both equally important to the experiment at hand.

Clues used:

Form III

Reading Test of Scientific English

This is a test of how well you can read and understand scientific English, The samples were taken from a scientific journal.

For Non-Native Speakers of English

1. Native language_____
2. Academic field_____
   Undergraduate_____
   Graduate_____
3. How long have you been studying in the U.S.?_____
4. Are you now enrolled in English 33 A?_____
   English 33 B?_____
   English 33 C?_____

   or

   Have you already completed English 33 A?_____
   English 33 B?_____
   English 33 C?_____

   or

   Have you been exempted from taking the above course?_____

For Native Speakers of English

Academic field_____
Undergraduate_____
Graduate_____

Instructions: 1. Read both of the following passages
2. Circle the statement (*a*, *b*, or *c*) that best describes the passages
3. Identify the clues (i.e. bits of information from the passages) you used in arriving at the answer

Passage A :

A canal-bottom sampler, used in Imperial Valley canals, California, by Fortier and Blaney, was constructed of a brass tube 2.7 cm in diameter and 15.2 cm long. At the bottom was attached a sharp steel cutting edge. The upper end of the tube was threaded into the base of a cone, the shoulders of which prevented the brass tube from sinking into the canal bed beyond the required depth. The upper end of the cone was attached to a handle of 1/2"-pipe, made up of short section coupled together so that the length of the handle could be varied according to the depth of the water.

Passage B :

The pictures were taken using the Viking orbiter vidicon cameras. These cameras are equipped with an array of filters covering the visible spectrum from 0.35 to 0.65 um. Three-color images are acquired using the violet, green, and red filters. Color scenes can be reconstructed by photometrically correcting and balancing such images to synthesize the blue, green, and red components. By acquiring multiple arrays of frames in each filter, three-color mosaics are built up covering large regions.

Please circle either *a*, *b*, or *c* :

a. *Passage A* describes an apparatus designed for a specific experiment; *passage B* describes an existing apparatus that has been used in, but not specifically designed for, that experiment.
b. *Passage A* describes an existing apparatus that has been used in, but not specifically designed for, that experiment; *passage B* describes an apparatus designed for a specific experiment.
c. Both *passage A* and *passage B* describe an apparatus designed for a specific experiment.

Clues used :

The following are taken from two introductory paragraphs of an article entitled *On a Vasoactive Peptide in the Rabbit Serum.* Both describe the state of past research related to the experiment presented in the paper.

Instructions: 1. Read both of the following paragraph fragments
2. Circle the statement (*a*, *b*, or *c*) that best describes the paragraph fragments given

3. Identify the clues (i.e. bits of information from the paragraphs) you used in arriving at the answer

A. Morton and Tainter (1967) found that the vasoconstrictor potency of ephedrine in the perfused hind limb of the cat was much higher in the presence of plasma or serum.

B. Wurzel (1973) has recently reported that the isolated rabbit aortic strip suspended in Ringer is very insensitive to ephedrine, whereas the pressor potency of ephedrine is unexpectedly much higher.

Please circle either *a*, *b*, or *c*:

a. The past research described in *A* is more directly related–in terms of importance–to the experiment at hand than the past research described in *B*.

b. The past research described in *B* is more directly related–in terms of importance to the experiment at hand than the past research described in *A*.

c. The past research described in *A* and *B* are both equally important to the experiment at hand.

Clues used:

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