Categories of Information Conveyed by Condition Sentences in Scientific Writing

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My aims in a project I am currently working on have been:

a. to determine what categories of information are conveyed by conditional sentences used in scientific writing,
b. to see how these different categories of information might be analyzed and presented in sentence structure frames, and
c. to develop writing lessons and exercises for first and second year university science students based on the results obtained.

My procedure was to collect all the conditional sentences I could find in 8 basic science texts (see bibliography) to use for my raw data. The structure frame for the type of conditional sentences collected can be represented in its most basic form as:

If CODITIONAL CLAUSE, (then) MAIN CLAUSE.

The categories of information which emerged from the raw data include three (III, IV, and V below) which have long been well known and might have been predicted, and two (I and II below) which came as something of a surprise. These latter two categories surfaced with such frequency in the 8 science texts examined that I am convinced they are as significant as the better known three and should certainly be dealt with in any course on writing scientific English. All five categories are presented here. Under each I have listed some of the science text sentences exemplifying that category. These sentences from actual science texts are headed by one or two examples of my own making, offered as simpler illustrations for the non-scientifically oriented reader to consider.

CATEGORY I: GOAL (DESIRED RESULT)/PROCEDURE (REQUIRED CONDITION)

Analysis: All "goal/procedure" conditional statements contain:

a. a description of some desired goal or state, and
b. a description of the procedure to be followed or the condition to be provided in order to reach that goal or achieve that state.

Examples:

a. If you want to get good grades, you should study regularly.
b. If a student is to pass the course, he must be present for at least 80% of the lectures.
c. If two particles are to react, they must....collide. (Parkes, 251)
d. If we wish to find out whether metal A is more or less active than metal B, all we have to do is to place metal A in an ionic solution of a compound of metal B and see if A replaces B. (Booth, 503)

A conditional sentence structure frame for expressing this category of information might be represented as:

If	CLAUSE DESCRIBES DESIRED GOAL OR STATE	,	(then)	MAIN CLAUSE DESCRIBES PROCEDURE TO BE FOLLOWED OR CONDITION TO BE PROVIDED.

It is interesting to note here a reversal of the information generally associated with the two clauses. Normally, we expect the if-clause to state the condition (in fact we often call it the "conditional" clause), and the main clause to state the result. Here, however, it is the main clause which describes the condition (procedure) needed and the if-clause which describes the result or desired goal. Strictly speaking, the if-clause of "goal/procedure" conditionals does state a condition, but this condition is trivial in terms of the information content of the statement. It is simply saying, "If someone wants to get a certain result...." We might call this a "rhetorical" condition (on analogy with a rhetorical question), since the writer has obviously assumed that someone does want to get the result in question or there would be little point in describing how to go about doing so.

The if-clause in "goal/procedure" conditionals is characterized either by verbs of volition ("want", "wish") or by the phrase "*be* + to VERB" ("are to react"). Various modals are used in the main clause to indicate necessity ("must"), strong recommendation ("should"), or one out of two or more ways of achieving the goal ("can", "may"). Obviously here too, the verb phrase in the main clause could be an imperative ("If you want to get good grades, *study* hard!"), but I came across no examples of this in the 8 science texts I examined.

The "goal/procedure" conditional with "must" in the main clause always expresses a *necessary* condition (which may or may not also be *sufficient*). It is equivalent to the negative conditional with "unless", For example, statements c. and c_1. below are saying the same thing (the context is a discussion of chemical reaction):

c. If two particles are to react, they must collide.
c_1. Two paticles will not react unless they collide.

We can contrast these two statements with conditionals of the type illustrated by c_2.:

c_2. If two particle collide, they will react.

Conditionals of this type (with present simple tense in the if-clause and the modal "will" in the main clause) can only be used with conditions that are *sufficient* (they may or may not also be *necessary).* Statement c_2., then, is not synonymous with c. and c_1.; and indeed, c_2. in this case is false (in order to react chemically, it is not sufficient that two particles merely collide). Writing exercises for students will have to develop their ability to discriminate between conditionals such as c. and c_1. which are appropriate for necessary conditions but wrong for conditions which are only sufficient, and c_2. which is appropriate for sufficient conditions but wrong for conditions that are only necessary.

One such writing exercise can be something like the following:

A. GIVEN TO THE STUDENT: Depriving a fish of oxygen is enough (sufficient) to cause it to die.

STUDENT WRITES: If a fish is deprived of oxygen, it will die,

B: GIVEN TO THE STUDENT: It is necessary for two particles to collide in order for them to react chemically.

STUDENT WRITES:
a. If two particles are to react chemically, they must collide.
b. Two particles will not react chemically unless they collide.

CATEGORY II: CHALLENGING A HYPOTHESIS

Analysis: All conditionals of this type contain:

a. a description of some hypothesis (theory, law, principle, or belief) whose validity is challenged, and
b. the observed fact or experience (usually in the form of a rhetorical question) which seems to contradict the hypothesis.

Examples:

a. If you are so clever, why can't you answer my question?
b. If a substance like $_{92}U^{238}$ is unstable, why is there any left? (Borowitz, 784)
c. You would probably wonder why, if the earth travelled so fast through space, there were no strong winds blowing in the opposite direction, and why birds were not left behind in their flight. (Booth, 17)
d. There were a number of objections (to the caloric theory of heat).... The second is that of an apparent contradiction. If adding caloric to a substance caused it to get hotter, how could "squeezing it out" as in friction also cause a rise in temperature? (Booth, 199)

Most of the above conditionals were used, in their fuller context, as rhetorical questions introducing a discussion in which the conflict between observed phenomena and challenged hypothesis turns out to be only an apparent one. In other words, the writer was anticipating a reader's possible objection and was showing the reader how the problem could be successfully resolved.

The structure frame for this category of information might be represented as:

If	CLAUSE DESCRIBES THE HYPOTHESIS BEING CHALLENGED	,	(then)	MAIN CLAUSE PRESENTS EVIDENCE WHICH APPARENTLY CONTRADICTS THE HYPOTHESIS (OFTEN IN THE FORM OF RHETORICAL QUESTION).

CATEGORY III: ANALYTICAL STATEMENTS

Analysis: In all statements of this type, two propositions are presented, such that either they are logically equivalent or one can validly be deduced from the other.

Examples:

a. If 1 is added to 1, the sum is 2.

b. If you state (the volume) as 284.115 cu. in., you are saying that it lies between 284.114 and 284.116 cu. in. .... . (Booth, 82)

c. For a given number of atoms of tin and the same number of atoms of oxygen there will be one atom of oxygen for each of tin. .... If we double the number of atoms of oxygen present, there will be two atoms of oxygen for each atom of tin. (Booth, 244)

d. If the direction of motion changes, even though the speed is unchanged, the velocity is not constant, because by definition, constant velocity implies no change in either magnitude or direction. (Borowitz, 48)

This conditional can be used for syllogistic reasoning as well as for conditional reasoning, with the major and minor premises stated in the if-clause, and the validly drawn conclusion in the main clause, e.g.:

e. If Socrates is a man and all men are mortal, then Socrates is mortal.

The structure frame for conditionals of this type might be represented as:

If	CLAUSE STATES THE GIVEN PREMISE(S)	,	(then)	MAIN CLAUSE STATES THE LOGICALLY NECESSARY CONCLUSION(S).

CATEGORY IV: DEFINITION

Analysis: All definition statements contain:

a. the name of the thing being defined (which we can call "X")

b. the name of a SET of which X is a member, and

c. the DEFINING PROPERTY or properties in terms of which X is distinguished from all other members of the set.

Examples:

a. A closed plane figure is called a triangle if it has three sides.
b. A soil is called a loam if it has about one-half sand, one-fourth silt, and one-fourth clay. (Villee, 133)
c. Birds are said to be resident if they occur all the year in one area. (Neal, 107)
d. If gypsum occurs in clean, fine-grained masses, it is called alabaster; if in translucent crystals, it is known as selenite. (Parkes, 704)
e. If a particle in periodic motion moves back and forth over the same path, we call the motion oscillatory or vibratory. (Resnick, 342)
f. Water is said to be hard when it contains certain classes of dissolved impurities. If the water contains bicarbonates of calcium, magnesium, and iron, it is said to have temporary hardness. (Selwood, 175)
g. If more than one bond exists between two carbon atoms,....the valencies are said to be unsaturated. (Booth, 569)

A structure frame for conditionals functioning as definitions might be represented as:

(A MEMBER OF) SET	be	called	X	if	CLAUSE DESCRIBES THE DEFINING PROPERTY OF X.
		termed			
		said to be			
		known as			

Definitions expressed in this conditional structure can also be expressed in the structure which states what X and its set are in a main clause, and which gives the defining property of X in an adjective clause. Thus, a. and a_1. below are saying the same thing (i.e. are both giving the same definition of a triangle):

a. A closed plane figure is called a triangle if it has three sides.
a_1. A triangle is a closed plane figure which has three sides.

CATEGORY V: CONDITION/PREDICTED CONSEQUENCE

Analysis: Conditional statements in this category seem to be by far the most common in scientific writing. Such statements tell us the results or consequences predicted and expected under the given condition according to all the currently accepted laws, theories, and hypotheses of science. When a person says, "If a ball is tossed up into the air, it will eventually fall back again to the ground", he is saying, in effect, that if the laws of gravitation as they are currently accepted by physicists are true, then this is what must happen. This is the conditional that also tells us what results are predicted by a tentative hypothesis under conditions that could be provided in a test experiment (as in statement b. below.)

Since examples of this type of conditional abound and are doubtless quite familiar to the reader, only a few will be given below.

Examples:

a. If a ball is tossed up into the air, it will eventually fall back again to the ground.

b. If laboratory rats are fed on a diet lacking in vitamin C, they will develop scurvy.

c. A strip of metal will increase in length if (it is) warmed.... (Borowitz, 331)

d. If a gun is fired from a horizontal position at the same instant that a boy drops another bullet from the same elevation to the ground level below, the two bullets will reach the ground at the same instant. (Booth, 110)

e. If a ball is simply held in the air and dropped, its velocity increases steadily until it strikes the ground. (Krauskopf, 22)

The structure frame for this type of conditional might be represented as:

If	CLAUSE STATES THE GIVEN CONDITION(S)	,	(then)	MAIN CLAUSE DESCRIBES THE PREDICTED CONSEQUENCE(S).

In gathering raw data from science texts to determine what categories of information are significant and how these categories are expressed in the text, there are two approaches which can be adopted, each with an inherent bias. The two approaches are complementary, however, since the bias of each tends to correct for the bias of the other.

In one approach, we can begin with a given structure as our criterion for selecting the raw data and then proceed to see what categories of information emerge. The bias here would result in our failure to discover any significant categories which were never expressed in the structure we began with.

In the other approach, we can begin with a given category of information as our selection criterion and then proceed to determine, from the raw data collected what structures (or, for that matter, whatever concatenations of words in the text – phrase, clause, paragraph or whatever) are used to express the given category of information. The main problem in using this approach is the problem of determining beforehand what the significant categories are. It is easy enough to begin with the well-known and long established ones – e.g. Definition, Measurement, or Comparison, to name some. But when these are exhausted, does it mean that no others remain, still waiting to be "discovered"? Even with these better known categories, there is the problem of dealing with overlapping functions and inter-relationships. For example, consider the following :

a. Osmium is a metal whose density is 22.48 g/cm^3.

b. Osmium is denser than any other metal.

Statement a. can be classified as Measurement, b. can be classified as Comparison, and both can be classified as Definition. How are these overlapping functions and interrelationships to be dealt with in sequencing lessons and writing materials for students? If statements of type a. are included in a writing unit on Measurement, are they then to be excluded from a unit on Definition (because "the student has already done them in the Measurement unit")? Should a unit on Measurement include, perhaps, a section on significant subsets of Measurement statements, one of which would be that Measurement statement which can also function as Definition?

Even the best of the currently available textbooks for teaching the writing of English for science fail to deal with problems of this kind and that failure is reflected in the arbitrary and often random order in which the various units of such textbooks are simply "piled up." One would suspect that there must surely be a more effective and efficient way of sequencing such materials, based on a well thought-out system of categories of information in which overlapping functions and inter-relationships have been carefully analyzed.

My initial procedure, in the investigation described in this paper, has, of course, been the structure-biased one. From it, two potentially significant categories of information have emerged, tentatively called by me "goal/procedure" and "challenging a hypothesis." The fact that they occurred not only frequently, but frequently in a number of different science texts indicates that they are not idiosyncratic to the style of a given writer and argues well for their significance. To me they seem as significant as, say, Definition or Comparison.

What I plan to do next is to take these two categories (as well as the other three decribed) and use each as the selection criterion for a new round of raw data gathering. It will be interesting to see, for example, whether there are paragraph-length examples of "goal/procedure" (as I feel certain there will be.) In such examples, what logical sequence do the sentences describing "goal" and "procedure" follow? A sequence that immediately suggests itself for "procedure" is a temporal one, signalled but such sentence connectors as "First,.... . Next,.... . Then, ... Finally,.... ." One can begin to see, tentatively, how writing exercises based on "goal/procedure" might begin with goals and procedures which can adequately be described in the confines of a single sentence and then proceed to those which require "more words" to describe than a single sentence could manage.

The investigation procedures I have been discussing can be applied to any structure, category of information, or other "unit" chosen as the starting point. I strongly believe that if more efficiently planned and effective English writing materials are to be developed for science students, these are the kinds of procedures that must be followed.

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