Humanistic Mathematics Network Journal

Issue 24 Article 18

5-1-2001

Students and Their Learning From Reading

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INTRODUCTION

My aim in this article is to summarize work I have done over the last three years, focusing on the issue of helping students learn from whatever mathematics text they read. Although these types of texts generally contain 3 modes of communication, namely technical English, the language of mathematics itself and diagrams, I will focus this article only on the technical English of such texts. The idea, then, that students can develop techniques and strategies for learning from what they read is generally known as "reading to learn."

AN OVERVIEW

Now, mathematics courses cover a variety of subjects from statistics and O.R. to pure mathematics to applied mathematics. I mention this only to point to the fact that the textbooks students use to read, and hopefully learn from, are written in such different styles and contain such depth of detail that they have great problems developing an understanding of what they read. Statistics texts tend to be written in a more prosaic and descriptive style than that of applied or pure mathematics texts which usually tend to be very tightly structured in terms of language, containing a high concentration of technical words.

Given this, and the fact that students spend more time trying to learn from written material than having access to a teacher who can support them in their learning, it might be beneficial for them to be able to learn how to go about reading meanings into the texts they read, and as a result learning from these. Consequently, the realm of reading-to-learn part of my work has focused on developing techniques which allow students to develop an ability to read to learn from text written in plain or technical style of language by adopting an interpretive approach to their reading. Supporting students' learning from reading is done via the use of text manipulation and gist elicitation techniques aimed at allowing students to develop their own personally significant meaning and understanding of the text.

INTERPRETATION IN GENERAL

One thing that always troubled me, early on in my teaching career, was the fact that whatever assignments I used to give my students, I could never be sure that they understood the work they presented me in return. The fact that any particular student obtained a grade A or B was no guarantee that s/he actually understood the work clearly enough to be able to explain it to me in conversation.

Separately, I went through a personal experience relating to the writing of a set of course notes on the subject of Laplace transforms. It was in me having trouble finding a suitable analogy of what a transform was, and then resolving the issue by actually organizing my ideas, writing them down, reorganizing my ideas and rewriting them down, that I realized that it was in my attempt to interpret and reinterpret the subject that I actually learnt about it and how to present it.

By this experience it became clear to me why I wanted to include an element of interpretation in any work the students presented. In deciding to adopt an interpretative approach to the assignments I would give my students, I felt I would be able to see more clearly the degree to which they would illustrate their understanding. Also, their attempts at having to explain themselves in detail would provide the opportunity for deeper learning of the subject.

Since then my ultimate aim has always been to get students to interpret the text and mathematics of what they read. Consequently, in respect to a text being read, I mean *interpretation* to be:

a personally significant and valid re-description of the original text, based on the ever more refined and cultivated meaning you image of that text.

I shall therefore adopt this as the working description of "interpretation." An example of a text which a student would have to interpret in order to understand

and learn from could therefore be something like:

In elementary combinatorics it is shown that the number of partitions P(n,m) of a natural number n into m (not necessarily distinct) summands can be calculated with the recursion formula...

(G. Walther 1986), or

Confidence intervals and hypothesis tests based on large samples $(n \geq 30)$**, discussed previously, rely on the fact that the statistic**

$$\frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

has approximately a standard normal distribution when $n \geq 30$**. This follows from the Central Limit Theorem discussed in section 7.7.**

(Chase and Bown p. 358, 1997). What generally tends to blind students about these types of definitions and expressions is the technicality/density of the language. To overcome this problem of non-understanding based on the type of language, students might then want to interpret these technical definitions *in plain English*, and more specifically in their *own* plain English, in order to develop a level of understanding of the technical language.

It would then be in the act of attempting to interpret the above definitions that students would be in a process of constructing a meaning to them. Given that their initial interpretations would probably be vague, incoherent and incorrect in parts, they could then go about refining these into more coherent, precise and correct descriptions.

What should be borne in mind here is not that I am advocating the simplification of the language of mathematics but that I am advocating its simplification as a means to developing a learning of mathematics, with continued interpretation as the process for that learning. Once the student has learnt to interpret and read the text, s/he will naturally talk about the subject at the more rarefied level of communication that more experienced mathematicians take for granted. The advantage from the student's perspective, however, is that s/he will now do so from a much stronger and personally more meaningful basis.

But, in order to do this, students need to learn how to read in order to use their reading as a basis for their learning. This implies that they need to use certain techniques for reading. However, beyond the mere use of techniques lies the domain of "strategy." Students need to be able to organize the way they use the techniques when reading-to-learn, depending upon the style of text they are reading (such an area lies beyond the scope of this article).

TECHNIQUES FOR INTERPRETING TEXT

The specific techniques which I have developed over the past three years can be classified into two families:

1) A family of techniques designed to help students interpret the detailed, micro level of the text that I call *KE**
2) A family of techniques designed to help students interpret the general, macro level of the text that I call Text Levels.

MICRO LEVEL TECHNIQUES: KE*

This family of techniques arose out of an experience I had with a student who had come to me for help with one of her subjects. Based on a set of notes her lecturer had given her, I proceeded to read a part of it and asked her if she understood a particular sentence relating to the definition of the word "stress" as relating to engineering. The sentence was:

The distribution of force across a section is called stress.

When she told me that she had not understood the sentence, I told her that the sentence didn't have to be written the way it was. I then showed her other ways the sentence could have been written; I did this by swapping parts of the sentence around to get:

Stress is the distribution of force across the section.

Another attempt at finding alternate ways of restructuring the sentence led me to:

Force across the section is called stress if it is distributed.

It is this last variation which led me to have an epiphany. Whereas previously I believed that I had

completely understood the original definition, it was only with this last interpretation that I realized that I hadn't (well, not completely). It was in putting the word "distributed" at the end of the sentence that I finally understood the need for the force to be distributed. This is a point I had not been consciously aware of the necessity of. It then seemed that, in placing this word at the end, a greater emphasis was placed on it and allowed me to give a greater meaning to the term "stress."

I then came to name this technique of interpretation *Key Element Permutation* (KEP), whereby a person may choose any element of text as the key part to work with, and then permute them in any order. From this s/he would have to develop a grammatical and meaningful sentence around the new order of the elements.

After this I developed other text manipulation techniques which, when used in combination with KEP, would provide students with ways of interpreting what they read. The two other main techniques were

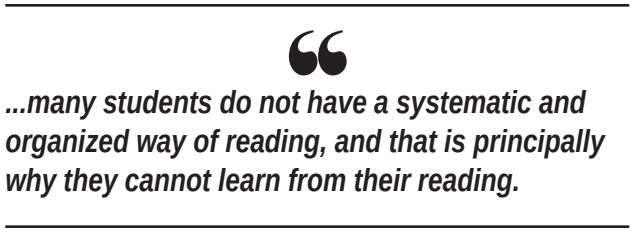
Key Element Substitution (KES)
Here students swap chosen elements of text for either synonyms or elaborated explanations that they believe are most relevant. Such an approach to reading allows then to recast text in a personally more appropriate language, one which they understand fully. Such a language can then act as a point of departure in terms of refining their interpretation towards the level of language of the original text.

Key Element Deletion (KED)
Here students simply go about deleting parts of the text they feel are not necessary (what is defined as necessary or not tends to be discussed in conversation) to see if this helps focus in more clearly on the main theme of the text.

My experience in supporting student reading-to-learn suggests that KED is by far the simplest technique for them to put into practice from which useful meaning of text can be derived. KES is slightly more difficult to use for the purpose of interpretation since they are more unsure of what synonyms to use or how to elaborated upon the text. Indeed, their substitutions tend to be quite vague and imprecise (which is to be expected for text they do not fully understand).

KEP is by far the most difficult since they are never quite sure where to break the text up into elements or how to construct a new sentence around the way they have newly ordered the elements.

Now, you and I may recognize in these techniques aspects of the way in which we already read. The point is that many students do not have a systematic and organized way of reading, and that is principally why they cannot learn from their reading.



As an example, consider the G. Walther text presented earlier. Deleting certain elements and using synonyms for others one might develop an initial interpretation to be:

In (...) combinatorics *we can see* that the number of *splits* P(n,m) of a (...) number (...) can be calculated with the (...) formula ...

where those elements deleted are represented by the parentheses, and those element synonymized are represented in italics. Then, swapping parts of this sentence around may help to generate an alternative emphasis on it and therefore inform a new understanding to the student. Consequently, a student may develop:

A formula can be used to calculate the number of splits P(n,m) of a number.

As an *initial* interpretation this may be exactly the kind of description that the student understands. S/he may then develop a sequence of ever more refined interpretation leading towards the original text, but this time starting from a position of understanding and from a process of knowing how to interpret.

Macro Level Techniques: Text Levels (TLs)

This family of techniques, designed to help students focus in on the general gist of what they read, came to me during a class I was teaching on discrete math. I went into the very first lesson of the semester intend-

ing to guide students in their reading to learn using KE*. I had therefore decided to start the lesson by talking generally about a passage of the text we were using when it gradually dawned on me that I was interpreting the passage and doing so in an ever more generalized manner. I then realized that I was giving a one to two word descriptor to each of the particular paragraphs we were reading, and that in doing so it could be said that I was interpreting the gist of the paragraph.

In subsequent lessons I realised that I was adopting the same approach of "gist" interpreting the text, but this time for groups of sentences and then for individual sentences themselves. From this I thought of a hierarchy of "gist" interpretations based on the level of text, these being paragraph level, "groups of sentences" level, sentence level, etc...

Hence the idea of *Text Levels* (TLs) came to mind. They then have as their aim to allow students to elicit a meaning to the passage they are reading by initially *guiding* them into seeing whatever general idea(s) of the text they can. This guidance is given by the asking of an appropriate type of question such as "What is the text an illustration of?" or "What is the passage an example of?" The questions can then be altered to focus on whatever level of text the teacher may wish to guide their learning in.

As an example of the use of TLs consider the paragraph by Chase and Bown presented earlier. In order to focus the student's mind towards a particular level of text we might ask him/her, "What is each phrase of the sentence an illustration of?" from which a student may then interpret the text at the phrase level as:

for the 1st sentence
1st phrase: "Confidence intervals and hypothesis tests"
phrase interpretation: statement of techniques

2nd phrase: "based on large samples $(n \geq 30)$"
phrase interpretation: recap or summary

3rd phrase: $(\bar{x} - \mu)/(\sigma/\sqrt{n})$
phrase interpretation: formula

4th phrase: "has approximately a standard normal distribution when $n \geq 30$"
phrase interpretation: statement

for the 2nd sentence
1st phrase: "This follows from"
phrase interpretation: linking or justification comment

2nd phrase: "the Central Limit Theorem discussed in section 7.7."
phrase interpretation: naming of theorem

From this we can see that concentrating on the phrase level of text should help focus the student into constructing a more specific meaning to the text.

Beyond merely interpreting the gist of a particular level of text, there remains the fact that they need to be able to interpret the chunk of text as a "whole." Having interpreted the gist of the paragraph phrase by phrase, the aim now would be for them to be able to synthesize these descriptions into a coherent summary. This is done simply by creating a sentence or two out of the separate text level descriptions in order to develop a *Text Level Construction*. For example:

"This paragraph talks about some techniques and then makes a summary. It then shows a formula and makes a statement, and finishes with a statement and names a theorem."

With this interpretation in mind, the student may then compare with the original text to personally judge the viability of his/her understanding of the original text.

Now, the importance of constructing a sentence from previously separate text level descriptions should not be underestimated as a learning opportunity. By the process of creating a TLC the student now has the opportunity to develop the ability to express, clearly and coherently, the meaning s/he has generated from the text, and do so from his/her level of language. In doing so it makes explicit the extent to which the student has been able to construct a whole-meaning to the text.

The whole purpose of these techniques is to allow students the ability to develop a fairly detailed and precise meaning for the text they are reading. Consequently, a student would aim to develop a final interpretation such as:

"This paragraph talks about how two types of statistical analyses, which use a particular formula, are

based on a specific requirement. A particular theorem is then stated as justifying the validity of this requirement."

It would be a trivial step for the student to then identify the particular types of statistical analyses (i.e. confidence intervals and hypothesis testing), the particular formula, the specific requirement (i.e. normality) and the actual theorem used as justification.

HOW IT ALL WENT

All in all, having settled down in my own learning of how to guide student learning, the vast majority of students came away with a much improved ability at learning mathematics (certainly all of them thought that, at least, this was a useful experience to go through even if they did not intend to carry on with this approach to learning the subject).

They were able to read into math a meaning they had not previously seen or even thought they would be able to see. As a consequence of this, their personal attitudes towards the subject of mathematics itself were considerably changed for the better. So, not only has their level of math improved, but they can now see how they themselves might go about improving their level of understanding beyond that they developed in the sessions we had.

Furthermore, some of the students actually went beyond merely using this approach in their sessions with me in that they automatically went about looking, thinking about and learning from what they were reading in other modules of their courses, *without me ever having suggested that they do this*.

An example of the usefulness the techniques have had in supporting students' attitudes towards the subject and their learning of it can be seen in the excerpt of conversation below, which I held with some of my students at the end of the course. The three participants of the conversation below are myself ("C") and three students N, M and K.

C: How did [the module] compare to normal math modules that you might have done in the past?

K: At first when I first started the module I was thinking, "Well, is this math or English?" But then I understood why you were doing it because I was starting to understand the subject and pick it up faster.

N: Yours [the lecturer's] was a better method.

K: [...] your approach was so much different, so much easier. I mean, I can read anything now, that I might not have been able to before in math.

M: I thought it was excellent. Yeh. It just let you think about math in a different light, a different way. I found it making math so much easier. Yeh, I used it elsewhere. Because in some of my lectures you've got loads of information. [...] I even use the techniques for some of my exams because I just basically cross out some jargon. [...] So I thought it was excellent.

C: [...] Nimisha, any comments?

N: Well, I thought it was pretty good the way you taught us. I got to understand the subject more. The technique was really good because I could apply it, and I could understand the actual math. Before I couldn't do that.

C: [...] Right. So let me ask you again what aspects did you think you liked best in terms of content, the lessons themselves, the text reading stuff, anything, etc...

N: The text reading. I thought that was really good, and it involved the actual student. [...]

C: And has your view about your like or dislike about math changed?

N: Yeh, I like math now. (*Laughs.*) I never used to like it that much because I couldn't understand it. But now I can understand it; I enjoy doing it.

M: Well, I've always loved math, but math was never my strong point. But with this technique I can now use it and understand math a bit further. So, I found it really, really, really useful. (*Laughs.*)

C: What kind of insight do you think this [approach to the course] has given you into ways of reading or ways of learning?

N: Well, now when I look at something I feel that I don't have to understand it straight away, and I have something there that I can use to help me understand that paragraph in time. So it's good.

C: [...] What experience do you feel you have gained [and] what do you value about the experience?

N: I've learnt how to read text, and I've started to understand math better than I did before.

C: Right, and what do you value about having that experience?

N: Getting to know math better and actually working with it. Because I know I need math for everyday life, so I'm so glad that I've actually gained that knowledge, that understanding of knowing what each bit is, and getting to know my math better.

From these comments it therefore seems that, when used as a classroom activity to support learning, students are able to approach their reading in a way they were not able to before, and consequently understand and learn mathematics beyond what they had thought possible.

WHAT OTHERS ARE DOING

A plethora of reading techniques abound in the reading research literature (see for example *Reading Research Quarterly* or the *Journal of Reading*), most of which are based on developing students' abilities at comprehending the gist level of text. Schwartz (1980) tested the different demands required of readers to comprehend text at three different levels, namely whole text level, individual word level and letter level. Previous work (Meyer, Brandt, Bluth (1980), Rinehart *et al*. (1986), Richgels *et al.* (1987)) suggests that good readers, those able to identify and follow a text's major themes and relationships as well as the facts supporting these themes, use a structure strategy when reading, but that poor readers lack precisely this skill. Consequently, Meyer, Brandt, Bluth (1980) developed a structure strategy which was designed to follow the organization of the author's text structure and allow students to focus on finding connections between large chunks of the text they were reading, while Rinehart *et al*. (1986) studied students' abilities at summarizing what they read by getting them to identify and delete certain types of information, as well as relating the main ideas they found to relevant supporting facts.

Little has been done in terms of helping students read-to-learn at the micro level of text. However, some work in the area of manipulation-type techniques includes that of Straw and Schreiner (1982) who developed sentence-combining and sentence-reduction techniques for helping students better understand the text they were reading. Ross (1972) has concentrated on sentence manipulation and transformation techniques (although not in connection with reading comprehension) while Rinehart *et al.* (1986) and Brown, Campione and Day (1981) studied students' abilities at understanding texts by using, in part, the deletion of certain types of information in order to summarize the major and minor aspects of what they read. Bean and Steenwyk (1984) have also used elements of deletion, as well as substitution (based on the work of McNeil and Donnant (1982)), in order to improve students' summaries of the texts they were reading.

Weiss (1983) argues that the reason poor reading comprehenders are not poor listening comprehenders is that oral discourse is marked by (amongst other aspects) pauses which are not marked in written discourse. His rationale was therefore that students could develop into better comprehenders if such pauses were introduced into the text, this being done by segmenting its sentences. Weiss then tested two types of segmentation based on spacing out the phrases of a sentence according to either their grammatical/syntactic structure (of noun/verb phrases, or compound phrases which framed a particular idea) or their pausal structure (this being defined as a unit of utterance between two pauses of breath which would occur during the speaking of a particular sentence).

Other text manipulation techniques developed to improve reading comprehension include those of Weaver (1979) (*RRQ* 15(l)) who developed a way to solve sentence anagrams by using a word grouping strategy. Her aim was to improve reading comprehension by teaching students how to go about organizing their construction of sentences. Consequently, the sentence anagram technique required students to form a sentence out of a jumbled set of between five and fifteen words, each word having been written on separate cards. Students were then taught to construct their

sentences by attending to the general structure of language. Consequently, they grouped words into phrases and grouped phrases into sentences, thus providing a structural approach to the construction of their sentences (the students were taught to construct the phrases themselves by using a verb as the focus and "enframing" it by action words).

In fact, very little work has actually been done in reading-to-learn in mathematics. The two principal people involved in this area are Raffaella Borasi and Marjorie Seigel (Borasi *et al.* (1998), Seigel and Borasi (1992), Borasi and Seigel (1990), Seigel and Fonzi (1995)). The majority of these studies focus on the reading of narrative style texts and are based on an approach to reading known as transactional theory of reading which involves the reader in actively participating with the text s/he is reading. Consequently, the reader is supported in a new way of thinking and engaging with a text by certain techniques which aim to foster a generative approach to interpreting and learning from it. Four approaches these workers have developed include *Say Something* (a type of free association technique), *Cloning an Author* (which involves developing a map of the interrelationships between what the reader considers to be the important ideas of the text), *Sketch-to-Stretch* (in which the reader sketches an interpretation to the text) and *Enactment* (in which the reader aims to act out the story of the text).

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