BRINGING GRAPHICS DOWN TO EARTH

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A lot is known about using graphics as an aid to learning. While more remains to be learned, much of what is known isn't being used in education. This is a shame because the use of graphics is often desirable. This paper is intended to bring some of the graphics methods down to earth, so that teachers can learn how to take advantage of them.

The Graphic Sentence
Figure 1 shows the basic idea of a graphic sentence.

![Diagram of JIM and SALLY connected by an arrow labeled "likes"]

Figure 1. Basic idea of a graphic sentence

Seen here are two "elements", Jim and Sally, and an arrow joining them. So far one might conclude that the graphic sentence says something about Jim and Sally, but it isn't clear what it says.

Next is introduced the idea of the "key", which is what enables the graphic in Figure 1 to be translated into prose. The key for the sentence in Figure 1 is shown in Figure 2.

![Diagram of "key" for the graphic sentence]
The key tells us what the arrow represents and also the idea that the sense of the key is from the tail of the arrow to the point of the arrow.

Putting the key together with the basic idea, we have the complete graphic sentence portrayed as in Figure 3.

```
  JIM
   \        
    \      likes
     SALLY
```

Figure 3. The complete graphic sentence

Now the graphic sentence can be translated unambiguously into prose. What is says, in prose, is:

*SALLYLIKESJIM*

**Combining Graphics Sentences**

With the aid of the idea of a graphics sentence, one can now think about combining these. Suppose we know that Sally likes Jim, and we know that Jim likes Mary. Then we can show this as in Figure 4, which combines two graphic sentences into one map.

```
  MARY
    \   
     \  likes
      \ JIM
        \   
         \  likes
          \ SALLY
```

Figure 4. Two graphics sentences combined in one map
The reader might wonder whether there is any point to showing the two graphics sentences on one connected drawing. It would be possible to have them disconnected, one showing that Sally likes Jim, and the other showing that Jim likes Mary. The answer is that there may or may not be any point to it.

Suppose that we also knew that Sally likes Mary. Then the key could refer not just to an arrow connecting two elements, but instead to the path connecting two elements. Notice that the two arrows in Figure 4 do form a path from Sally to Mary.

A possible name for this kind of situation is a "flow-through relationship". If the key applies not just to a single arrow but to any directed path from one arrow to another, then we say that we have a flow-through relationship.

In the example shown in Figure 4, we have no way of knowing whether the relationship is flow-through or not. It would certainly be possible that Sally likes Mary, but there is nothing inherent in the relationship "likes" to enable us to know that Sally likes Mary just because Sally likes Jim and Jim likes Mary. It is quite possible that Sally doesn't even know Mary, and that Jim likes it that way!

Some relationships do have the property of flowing through. Let us examine this next.

**A Flow-Through Relationship**

Let us look next at a map whose key does correspond to a flow-through relationship. This map is shown in Figure 5.

![Figure 5. A map with a flow-through relationship](image)
Using the key only to reflect those graphic sentences that represent direct connections on the graph (called edges), we arrive at this prose translation:

- two is less than three
- three is less than four
- four is less than five

Now, realizing that the relationship is of the flow-through type, we can expand the translation to include these additional statements:

- two is less than four
- two is less than five
- three is less than five

This example illustrates that there is a certain advantage in graphics when the relationship is of the flow-through type. It is even possible to develop a way to compute this kind of advantage.

**The Graphical Advantage**

The graphical advantage \( A \) for a graph of the type being used here is defined as follows:

\[ A = \frac{\text{The number of prose sentences represented by the map}}{\text{The number of elements shown on the map}} \]

With this definition, it is easy to see that the graphical advantage of the map in Figure 1 is only \( 1/2 \), but that the graphical advantage of the map in Figure 5 is 1.5.

**QUESTION:** Suppose the numbers from 1 to 10 inclusive were placed in a structure like that in Figure 5, using the same (flow-through) key. What would be the graphical advantage of the map? **ANSWER:** 4.5

We are beginning to see that there can be a very substantial economy of space in using a map with a flow-through relationship, as compared with prose. Also the prose translation doesn't necessarily make very interesting reading, but it can all be reclaimed from the map when needed. Also we see that the graphical advantage is a measure of the economy associated with the map.
QUESTION: Suppose that, in Figure 4, the key is changed to read "weighs less than". Does this change the graphical advantage of the map? Why? ANSWER. The original key in Figure 4 is not known to be a flow-through relationship, hence we can say that the graphical advantage is only 2/3. Because the key "weighs less than" is inherently a flow-through relationship, changing the key in Figure 4 changes the graphical advantage to 1.

Feedback

Next some maps will be examined that have "feedback". Figure 6 shows a famous feedback situation.

```
Chickens

Eggs
```

Figure 6. A map with feedback

Here the prose translation is:

EGGS PRODUCE CHICKENS

CHICKENS PRODUCE EGGS

and the graphical advantage is 1.

Feedback is fairly common in problem-solving, but prose does not afford a very good way of handling it. A map, on the other hand, provides a nice discussion aid. This can be illustrated by using a feedback map to discuss the famous hog cycle. The map to be used is shown in Figure 7.

```
DECREASED HOG PRODUCTION

LOWER MARKET PRICES FOR HOGS

INCREASED HOG PRODUCTION

HIGHER MARKET PRICES FOR HOGS
```

Figure 7. A map of the hog cycle
The prose translation of Figure 7 contains 12 sentences, so the graphical advantage of the map is 3. Some of these sentences may seem a little strange at first, like "higher market prices for hogs leads to lower market prices for hogs", but you can verify that this is true in at least two ways. One way is to talk with some hog farmers. Another way is to look at how the profits of packing houses have fluctuated over the years. Bankers are also familiar with this cycle. They tend to loan money to farmers when hog production is low knowing that the farmers will use the money to step up hog production, and knowing also that loan payback can be achieved due to the higher prices to be obtained because hog production is low. When hog production is high, farmers tend to get so little for their hogs that they can't afford to produce as many and cut down on their loans.

This cycle helps explain some things that go on in American industry and farming. Corporations get into hog production and use their sophisticated analysis techniques to attempt to smooth out the fluctuations. Also they tack on other kinds of businesses so that even if the hog cycle is operative in their business, other parts of the business will help keep profits flowing when the hog business is weak.

Curriculum Development

One application of maps of the type illustrated here is in the development of curriculum. Theories of curriculum development suggest that what is needed consists of two hierarchical maps. One of them deals with the content to be learned, and positions the content elements in a learning sequence. For example, "addition should be learned before multiplication". (The key is "should be learned before", and it is a flow-through relationship.) The other deals with the learning process and specifies what actors should do what in what sequence, and with what learning aids.
Learner Development of Sequences

Most teachers would probably agree that one of the best ways of learning something is to prepare the materials needed to help someone else learn it. Learning by developing learning sequences is a powerful way to learn. Perhaps students should be given more opportunity to do this themselves. The method of "interpretive structural modeling" (ISM) lends itself to student development of learning sequences, and also lends itself to peer group discussion while the sequence development is underway.