An Exploration of Schematic Representations of Photosynthesis in Textbooks

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Instructors frequently use visual representations (e.g. textbook figures, animations) to communicate complex scientific ideas. Photosynthesis is one such concept that students traditionally have difficulty learning. In textbooks, photosynthesis is most often represented schematically using boxes, arrows and cartoons (Fig1).

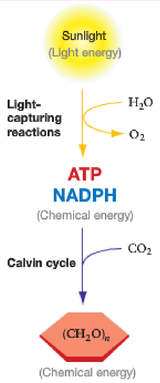


Figure 1

We hypothesized that schematics may confuse students because they are not always well explained, may be over simplified, or do not follow common conventions.

Goal: Characterize one part of schematics (arrows) to determine the:

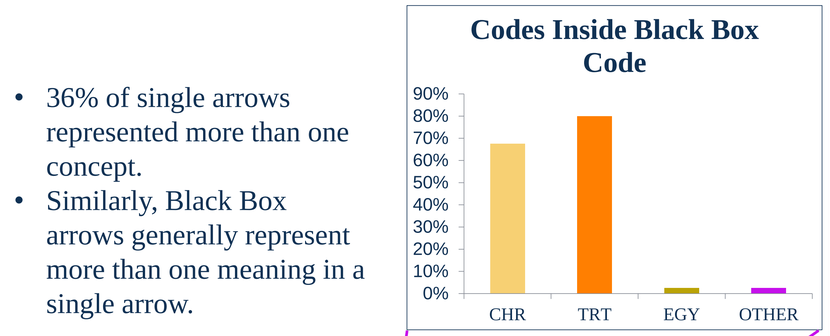
1. range of concepts represented by arrows, and
2. degree to which the meaning of arrows is made explicit.

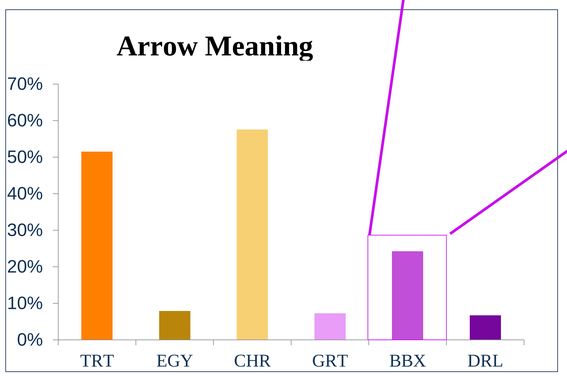
What do schematic arrows represent in photosynthesis?

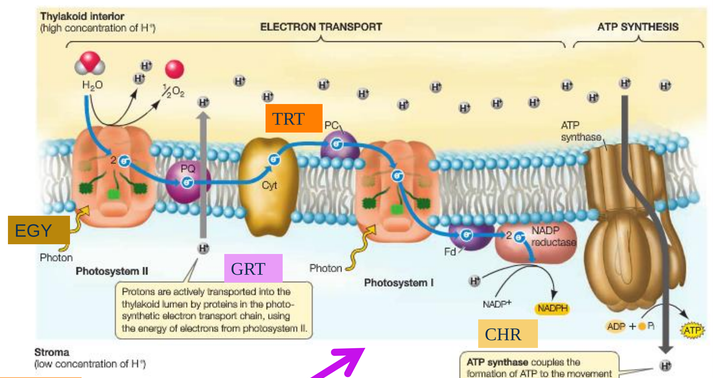
Five schematics from each textbook were analyzed.

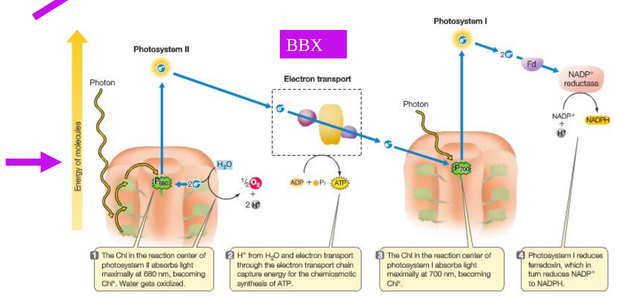
Meaning of the Arrows in Schematics	
Transport (TRT)	Physical movement from or through one location to another
Energy (EGY)	Input or output of energy. i.e. arrow showing sunlight being absorbed by a leaf.
Chemical Reaction (CHR)	Example: $NADP^+ + H^+ => NADPH$
Gradient (GRT)	Chemical or electrical gradients
Black Box (BBX)	A number of reactions, processes, or steps reduced to a single arrow.
Directional (DRL)	Directs reader's attention to a new area.

- 36% of single arrows represented more than one concept.
- Similarly, Black Box arrows generally represent more than one meaning in a single arrow.



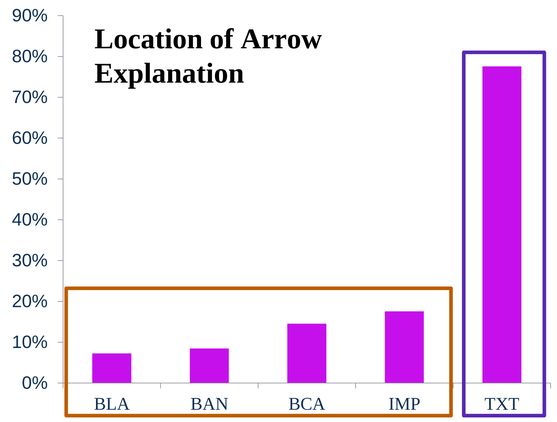






How is the meaning of schematic arrows explained?

Explicitness of Relationship Represented by Arrows	
Code	**Criteria**
Label (BLA)	Embedded in the figure itself using abbreviated text (e.g. above an arrow)
Annotation (BAN)	Annotated within the figure (e.g. pop out box or numbered box)
Caption (BCA)	Expressed within the figure caption
Text (TXT)	Found within the actual text related to that visual.
Implicit (IMP)	Not fully explained anywhere in the chapter.



Explanatory text was found solely in the actual text 70% of the time; 62% of these instances, the explanatory text is not even on the same page.

Independent of the text, the meaning of most arrows is implicit. The meaning is made explicit (BLA, BAN, BCA) only 30% of the time.

Discussion

Our results show that schematic arrows can have several meanings and some arrows have multiple meanings. If students are not made aware of these meanings, they could become confused. The Black Box arrows may be especially difficult for students to understand because they box several arrow meanings into one arrow. In order for students to understand the figures, the arrow meanings need to be explained. However we see that the majority of explanations are not even on the same page as the visual. This is problematic because according to Mayer's Multimedia Principle, student's cognitive load is reduced when a topic is presented as a visual with explanatory text. However, it becomes increasingly difficult for students to integrate the explanatory text and visual back together the farther the two are from each other (Cook 2006). If explanations to visuals are not on the same page the majority of the time, it may make it more difficult for students to process information and tie up their working memory.

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