Fishbone diagrams: organize reading content with a "bare bones" strategy

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Even though students frequently have reading assignments for homework, they often exhibit very little knowledge—much less comprehension—of the science content presented in the reading assignment. Different techniques for enhancing science comprehension for middle school students can be implemented before, during, or after reading assignments (Johnson and Martin-Hansen 2005). One teacher reported success with reluctant middle school readers by requiring students to draw summaries of the content (Elliot 2007). These student-created visual organizers can help to summarize science reading content, as well as determine the relative importance of the information contained in the reading assignment.

In addition to these reading strategies and summary drawings of the reading content, we propose the use of another graphic organizer for reading success: the fishbone diagram. Fishbone diagrams, also known as Ishikawa diagrams or cause-and-effect diagrams, are one of the many problem-solving tools created by Dr. Kaoru Ishikawa, a University of Tokyo professor. Part of the brilliance of Ishikawa's idea resides in the simplicity and practicality of the diagram's basic model—a fish's skeleton (Figure 1). Fishbone diagrams help students identify, organize, and visualize the contributing causes and effects underlying a particular complex, science-related problem or event. They are also useful for organizing parts-to-whole content found in many science textbooks.

The fishbone diagram organization

Ishikawa diagrams were first created in 1943 as a thinking tool by Kaoru Ishikawa, an engineering professor at the University of Tokyo, who pioneered quality-management processes in the Kawasaki shipyards in the 1960s (Business Excellence 2009). Ishikawa subsequently authored several books on quality control in addition to developing the concept of quality circles. In quality circles, volunteers identify problems and suggest solutions in order to optimize an organization's performance. Although fishbone diagrams have been historically associated with quality-management tools (Figure 2), they can offer science classrooms a practical strategy to visually organize science reading content.

In the fishbone diagram, the head of the fish represents the summative effect or outcome of the information presented in the fish skeleton (Figure 3). Each of the fish's ribs represents a cause that contributes to the final effect. Specific examples can be listed under each of these item causes on the horizontal branches. If subbranches are used, reasons or characteristics of each example can be listed. Therefore, fishbone diagrams can be relatively simple visual organizers or more complicated graphics with several levels of detail.

There are numerous cause categories, including human, natural, organism type, physical, chemical, biological, and geological. Other cause categories can include design, location, evolution, mechanism, limits, function, process, environment, age, history, and society.

While causes contribute to an outcome or effect, it is important to remember that we actually work backwards when constructing a fishbone diagram. We start by identifying the outcome or effect, and then finish the diagram by thoroughly identifying the main causes. If the number of causes on a fishbone diagram are limited, students must identify the most important categories that contribute to a single outcome. Our fishbone diagram (Figure 3) supplies only six causes.

Fishbone diagram templates

Fishbone diagrams are relatively easy to construct. With a rectangular or oval stencil box and a ruler, a teacher can quickly draw the lines and category boxes needed for the basic fishbone. Students can supply a fish outline, and embellish or personalize their completed diagrams. We have observed that personalizing a fishbone often leads to student creativity, as students or groups attempt to produce the "best" or most creative fish.

There are also free fishbone diagrams available online for educational use (see Resources). The Holt Online Learning site supplies teaching notes with lessons and tips for classroom use. With the fishbone planner file, teachers can print out blank paper templates for students, or request that students type their categories/causes and outcomes directly on the interactive PDF file. Teachers can also use the interactive feature to supply the outcome and/or cause categories for students. This can be especially helpful for modeling the process and guiding student inquiry when fishbone diagrams are first used in the classroom.
The Holt Online Learning fishbone diagram is arranged vertically, with the "head" or outcome at the top of the page and the categories or "ribs" radiating from the medial vertical "spine" (http://my.hrw.com/nsmedia/intgos/html/igo.htm). There is also a free electronic Word document template, arranged horizontally, at iSixSigma (see Resources). The user can enter the outcome and categories and then print the fishbone diagram.

Introducing fishbone diagrams in the classroom

We suggest that teachers model the diagramming process and use simple activities when introducing fishbone diagrams in a science classroom. One effective activity, outlined below, shows students who are unfamiliar with fishbone diagrams how to analyze a topic. In this activity, students explain how a "bone" from the diagram relates to the topic. The fishbone diagram is constructed as a group activity in class.

First, the teacher draws a large, blank fishbone template on the board, or projects an outline with a SMART Board or overhead transparency. Next, a hat or box is supplied that contains slips of paper, each with a category or cause. For example, when the class is studying animal cells, slips of paper can list cell membrane, endoplasmic reticulum, nucleus, cytoplasm, mitochondria, Golgi apparatus, and DNA. Selected students withdraw a named cause out of the box and state the outcome or effect (animal cell). The class can discuss where each cause category should fit into the diagram, with the most important causes nearest the fish head, or effect. The class can cooperatively complete the fishbone diagram and supply characteristics of the causes. In this example, students are also reconstructing the "whole" (animal cell) from the cell's parts.

Using fishbone diagrams to help students analyze science content

For initial use as a reading strategy, fishbone diagrams are effective and easily implemented when the science content contained in the reading assignment has a fairly obvious organizational hierarchy. As the fishbone diagram synonym--cause-and-effect diagram--implies, fishbone diagrams are particularly useful when dissecting and organizing causality, although this is not their only use. Fishbone diagrams are also useful part-to-whole graphic representations, where reading content breaks down an object into its component parts.

Teaching cause and effect to students

In order to model fishbone diagrams as cause-and-effect diagrams to our students, we should instruct them how to recognize both a "cause" and an "effect."

Simply stated, a cause is something that makes something else happen. Out of two events, it is the event that happens first. To determine the cause, our students should ask the question, "Why did it happen?" Conversely, an effect is what happens as a result of the cause. Of two related events, the effect is the one that happens second or last. To determine the effect, students should ask the question, "What happened?"

There are different types of cause-and-effect relationships in science. In a stated cause-effect relationship, the relationship is clearly established. (Example: High doses of radiation cause damage to human tissues.) With an unstated cause-effect relationship, students have to be taught to "read between the lines" to determine the cause-effect relationship. (Example: The logs were buried in a flash flood during the Miocene Epoch. Volcanic ash in the area contributed high concentrations of silica to both surface water and groundwater. Over time, the logs were permineralized with silica.) In a reciprocal cause-effect relationship, the effects may be part of a chain series. In this kind of structure, one effect causes a second effect, which may then cause a third effect. (Example: Light is refracted as it hits the water's surface. The light reflects from a quarter at the bottom of the swimming pool. The reflected light is refracted as it leaves the water. That light enters our eye and we see the quarter.)

Science writers use a cause-effect text structure to show order, inform, speculate, and change behavior (EDC 2002-2008). A cause-
effect text structure identifies the potential causes of a problem in an organized manner. Cause-and-effect structure is often used for teaching concepts in science. We can help our students to recognize cause-effect text structure by teaching them signal words that indicate a cause-effect relationship. Signal words can include the following: accordingly, as a result of, because, consequentially, if-then, for the reason that, hence, so, so that, therefore, and thus.

Fishbone diagrams in reading assignments

We suggest that fishbone diagrams be assigned as an organizational and visual tool for science readings after a classroom introduction to this diagramming technique. We further suggest that cause-effect relationships are thoroughly taught to students, and students have opportunities to cooperatively construct fishbone diagrams in group settings, before independent fishbone diagram constructions are assigned for science reading content. This will optimize students' identification of cause-effect relationships and help them determine the importance of reading content.

Following the classroom demonstration and cause-effect discussions, teachers can then supply students with a partially filled fishbone diagram that parallels the assigned reading. Teachers can provide a fishbone that lists the causes and the effect, and ask students to furnish the supporting horizontal reasons and details. Or, teachers can provide the fishbone diagram with only the effect listed, and have students fill in the causes for the fish ribs. Once students practice supplying details to fishbone diagrams and identifying causes, teachers can then assign blank fishbone diagrams for science reading assignments.

An assigned reading on potential climate change resulted in the fishbone diagram depicted in Figure 4. The effect was identified as "global warming," while the potential contributing causes are "C[O.sub.2] increase," "Methane increase," "Nitrous oxide increase," "Atmospheric water vapor increase," and "Lost permafrost." Supporting details for each cause are listed horizontally along the fish ribs, and were obtained from the details of the reading assignment.

In addition to diagramming causes and effects, fishbone diagrams have application for organizing the parts-to-whole discussions found in science reading content, such as that found in life science or biology textbooks. Figure 5 identifies the components and functions of a plant cell that help to make it distinctive from animal cells. Five categories are provided, including cell walls, photosynthesis, mobility, vacuoles, and cell communication. Supporting details and descriptors are provided under each category.

Fishbone diagrams are not only applicable in ecology and biology classrooms. They can be very useful to organize reading content in Earth science. In Figure 6, earthquakes, the effect, is supported by causes of plate characteristics, plate movement, energy release, elastic rebound theory, plate boundaries, and fault types. Each of these causes is further described with sub-branch details.

Scoring students' fishbone diagrams

Students' fishbone diagrams can be scored fairly quickly with a simple scale. For student-generated fishbone diagrams, we offer the following guidelines:

1. Is the head topic (problem's effect) appropriate?

(+ 4 points)

2. Are the main branches' causes appropriate?

(+ 1-6 points for up to six valid and brief causes )

3. Are the sub-branch explanations appropriate and succinct?

(+ 1-3 points for up to three valid causes per branch)

4. Are the science words spelled correctly?
5. Does the overall diagram communicate well?

(+1-2 points)

Within this scale, fishbone diagrams can score a potential 30 points for excellent construction. In our Figure 4 example, the fishbone diagram scores 26 points: 4 points for outcome, 6 points for cause categories, 14 points for sub-branch explanations (+2, +2, +2, +2, +3, +3), no point loss for misspelled words, and 2 points for good communication. We determined that our average grading time per fishbone diagram is approximately two minutes.

Extending fishbone diagrams in the science classroom

We have presented only an introduction of fishbone diagrams for middle school science classrooms, and their use with assigned science readings. However, there are many more reasons why fishbone diagrams should be used in science classrooms, and a multitude of ways in which they can be employed.

Fishbone diagrams can help maintain students' attention during in-class videos. Teachers supply the causes to students, who fill in the fishbone diagram sub-branch details while watching a video. Fishbone diagrams can also be used to teach science by inquiry. Therefore, they are also useful to generate scientific research outlines. They can be used to organize students' scientific writing. The analysis of fishbone diagrams trains students to break the "whole" into "parts." Fishbone diagrams can be used to clarify relationships between a problem and all of the possible factors, issues, and causes that are related to it. Fishbone diagrams can also be helpful for classifying factors related to a topic by generating categories, such as materials, people, or types.

[FIGURE 4 OMITTED]

Fishbone diagrams can effectively illustrate each cause's relative influence. The size of the bones (such as big bones, medium bones, and small bones) signals the relative impact of the causes. The larger bones closer to the head of the fish demonstrate a great impact, while bones that are further away from the head or smaller show a lesser impact.

Conclusion

We think that fishbone diagrams are well suited as organizing graphics for science reading assignments. Fishbone diagrams quickly show the "how" and "why" of science content. They can extend student thinking and help students focus on core content material. We invite middle school teachers to introduce fishbone diagrams in their science classrooms and use them to help students analyze the science content in reading assignments.

[FIGURE 5 OMITTED]

[FIGURE 6 OMITTED]

Resources


Lu, C.-C., J.-C. Hong, and C.-W. Tsai. 2008. The promotion of pupil's science achievement and scientific inquiry ability through the use of "5 why" scaffolding strategies--"How to make bread" module as a teaching example. Chinese Journal of Science Education 16 (4):
References


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