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AUTHOR	Champagne, Audrey B.; Klopfer, Leopold E.
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ABSTRACT

Described is how teachers can use the Concept Structuring Analysis Technique (ConSAT) as a diagnostic, learning, and assessment task in teaching science. In essence, ConSAT assists students in organizing concepts on paper so that they may link what they already know to what they have to learn. The technique thus applies the philosophical notion of discipline structure and the psychological notion of knowledge structure to science instruction. In addition to illustrating ConSAT's use in teacher-student interactions and in assessment, the application of ConSAT to instruction in reading science texts and in answering science problems is discussed. (Author/WB)

LEARNING RESEARCH AND DEVELOPMENT CENTER

1980/19

USING THE CONSAT: A MEMO TO TEACHERS

AUDREY B. CHAMPAGNE AND LEOPOLD E. KLOPFER

University of Pittsburgh

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Audrey B. Champagne and Leopold E. Klopfer

Major Contributors:

Tela C. Zasloff
Alphones T. DeSena
David A. Squires

Learning Research and Development Center

University of Pittsburgh

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Abstract

In the format of an informal talk with science teachers, this paper describes how the Concept Structuring Analysis Technique (ConSAT) can be used both as a diagnostic and assessment task for showing how students structure their knowledge and as a tool for teaching science subject matter. The paper shows that the ConSAT operationalizes the philosophical notion of discipline structure and the psychological notion of knowledge structure, so that these notions can be applied in science instruction. In addition to illustrating the use of the ConSAT in teacher-student interactions and in student assessment, the paper's largest section discusses the application of the ConSAT to instruction in reading science text and in composing answers to science problems.

USING THE CONSAT: A MEMO TO TEACHERS

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Introduction

We expect students to make links between what they already know and what they are being taught. When left to their own devices they often make the wrong links. Sally has to make links between terms that have no meaning to her. Let's try to guess what was going on in her head as she sat in class:

Teacher: We're going to talk about the metric system, a way of measuring weight, length, and time. Today we'll talk about weight.

Sally: (Weight? O.K.)

Teacher: There are some new words we'll be using. Please copy these from the board as I write them. "Ten milligrams equals one centigram."

Sally: [Copies it down.] (Milligrams? Centigram? I guess milligrams are littler than centigrams, whatever they are.)

Teacher: "Ten centigrams equals one decigram."

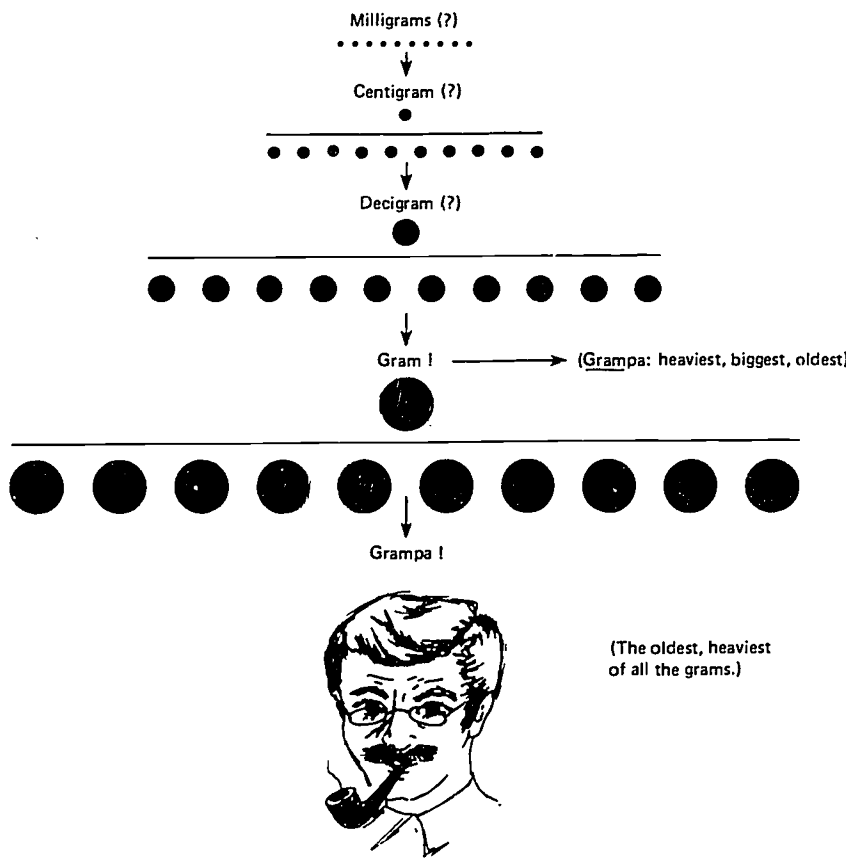
Sally: [Copies it down] (Decigram?)

<u>Teacher:</u> "Ten decigrams equals one gram."

<u>Sally</u>: [Copies it down] (Oh----gram! That's a part of <u>Gram</u>pa. I know that. Let's see---each time, a bunch of the littler things makes <u>one</u> of the bigger things, and they all have "gram" in them and they all keep getting bigger--and heavier? -- so the end one must be the biggest one--Grampa! Probably the oldest one too. I wonder --does that mean that a centigram is younger than a decigram and a milligram is younger than a centigram?

So, if ten milligrams make a centigram and ten decigrams make a gram, then ten grams make a grampa!)

If we would try to draw a picture of the links Sally made in her mind, it would look like this:



By a process of logical inference based on the link between one of the unknown words and a word very familiar to her, Sally has made sense out of what the teacher is writing on the board.

This example may seem silly, but every day children are engaging in learning tasks all too similar to Sally's, and all too often some wrong links are being made. Students are confronted with "nonsense" words--words that have no link to their own experience, so they make their own links.

Imagine now that the teacher gives the class a short answer test--a True-False Test--on the metric system, and corrects Sally's answers:

Ten grams is a decigram. T or F

Ten milligrams equals one centigram. T or F

The trouble is that the teacher really doesn't know why Sally chose her answers, both of which happen to be correct. Without the benefit of Schulz's wisdom, the teacher would assume that Sally knows that ten grams is not a decigram, that the terms have been reversed, when the truth is that Sally believes that ten grams is a grampa. The incorrect links have gone undetected and uncorrected. Note another example of an undetected set of incorrect links in the reasonable system worked out by Linus:

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To teach is to help the students build links between what they know and what they have to learn. As you well know, it is not always an easy task to figure out why Sally thinks a decigram might be older than a milligram or how to help her make a correct link between gram (a unit of measure of mass) and her experiences with the weights of objects. To figure out the answers to these questions you need to: (1) first, find out what information Sally has in her head and how that information is organized, and (2) then find an effective technique for organizing that knowledge in your teaching. Such techniques as underlining the major ideas in a book, making outlines, solving problems, making graphs or diagrams, doing experiments--all help to organize a subject but don't always help students see the relationships between ideas, an integrated structure of a subject as a whole.

It is to these two general tasks of the classroom teacher--to find out how the students are structuring their ideas and to determine how best to continue building on this structure--that we address this paper. We invite you to consider using a concept structuring technique developed through research and called the ConSAT (Concept-Structure Analysis Technique), which can be used both as a diagnostic and assessment instrument for showing how students structure their knowledge and as a tool for teaching the subject itself.

Research Background

"Structure" is a key concept in the physical and social sciences and in philosophy. In sociology there is social structure; in psychology, knowledge structure; in linguistics, deep structure. Philosophers often speak of logical structures and the structures of the scientific disciplines. This concept of discipline structure strongly influenced the science curriculum reform movement of the late 1950s and 1960s. Discipline structure, as a philosophical concept related to the teaching of science, was probably represented most thoroughly by Schwab (1964a, 1964b). Schwab argues that a principal focus of science teaching should be the discipline structure, not the isolated facts, laws, and theories on which instruction is all-too-often based. The gap in Schwab's argument was the absence of any operational definition of discipline structure. What is it? How do you teach it? How do you know when it has been learned?

We think a key to answering these questions lies in the psychological notion of "knowledge structure." Human beings have vast quantities of information stored in their minds. A question of interest to psychologists and teachers is how that knowledge is organized: are the individual pieces in random order or structured in some specified way? Given certain kinds of thinking tasks, people behave as if the information they possess is stored in memory in highly organized ways; further, it seems that "related" pieces of information are stored together in structured units. Psychologists call these units "knowledge structures." No one has ever seen a knowledge structure, but this theoretical notion is still very useful. A way to explain this is to refer to a well-known analogy of Einstein's. He used the example of the wristwatch to explain how physicists develop theories about the workings of nature. They can't actually see the mechanism inside the watch but can imagine an operating system that explains and even predicts the movement of the hands. In the same way, although we can't see the mind working inside the head, we can watch how people behave and imagine knowledge structures that accurately explain and predict overt behavior.

Now, to get back to discipline structure. The discipline structure of a science resides in the minds of the scientific experts--in their knowledge structures--and is reflected in their writings and research methods. Thus, to teach students the structure of physics, you would teach them to organize or structure their knowledge about physics as a physicist would--in short, to think like a physicist when doing physics.

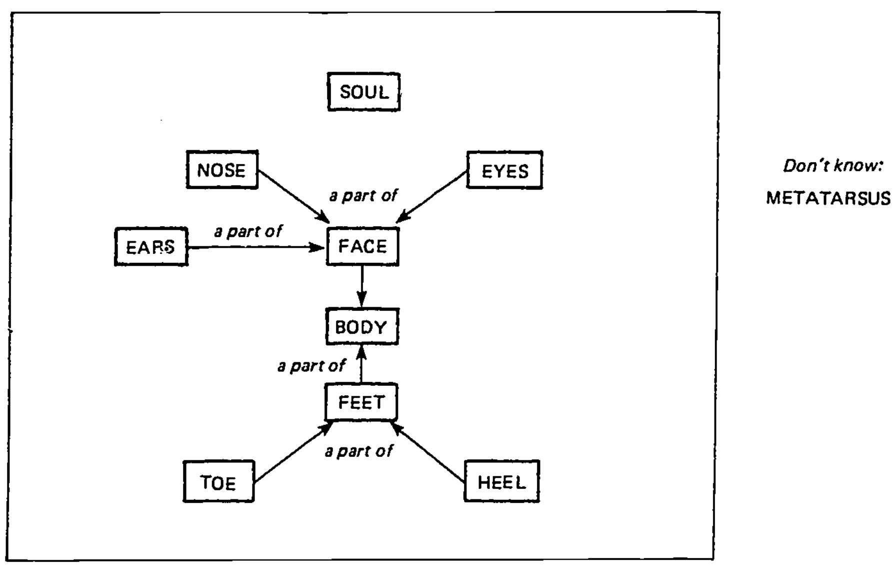
Science teachers need to know about the discipline structure of their field, the notion of knowledge structure and how both relate to learning. The ConSAT is an attempt to operationalize the concepts of discipline and knowledge structures for planning and assessing science instruction.

How It Works

Look over the following list of words and organize them in a way that reflects how you think about them. Any terms you don't know should be put aside.

BODY; EARS; EYES; FACE; FEET; HEART;
NOSE; SOUL; TOE; HEEL; METATARSUS

Can you now explain why you organized the words as you did? If you are like most people, your organizing principle was spatial and your structure looks something like this:



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The face is at the upper part of the body--the feet at the lower part. The eyes and nose are part of the face, and the toe and heel, part of the foot. The placement of soul is not so predictable. Does it surround the body like an aura or does it reside in the heart or the mind?

Now look at this list of nonsense words:

AUG; SBAG; YOG; KERLUM; PAG; WAK;
SOLFIME; BAB; PHANOK; ILESE

How will you organize them? Since there is no identifiable meaning or set of relationships, you will probably resort to listing the words in what is called graphemic patterns, such as alphabetical or rhyming order, or by the length of the words. For example:

Rhyme --AUG, YOG
Rhyme --SBAG, PAG
Two Syllables--SOLFIME; KERLUM; PHANOK; ILESE
Left Over --BAB; WAK

This kind of organization is common with children who try to relate terms completely unfamiliar to them.

Now look at the following list of geology terms. Again, organize the words in a way that shows how you think about them.

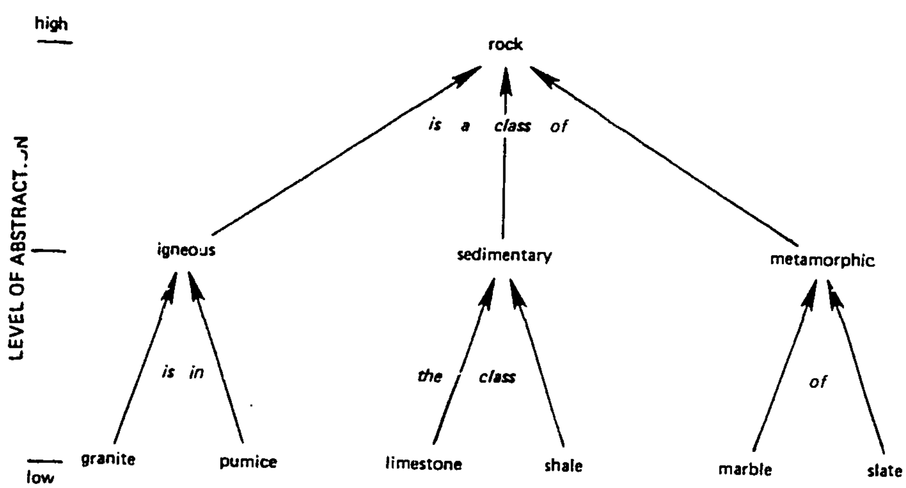
IGNEOUS; GRANITE; LAVA; ROCK; METAMORPHIC; SLATE;
MARBLE; SHALE; SEDIMENT; PUMICE; SEDIMENTARY

Explain why you organized the words as you did. How would an expert organize them? Does your structure represent the discipline structure, as expressed in the expert's structure? Did you relate one group to another in any way? What does the total structure of these groupings look like when you put it on paper? How many unfamiliar words would you need to look up?

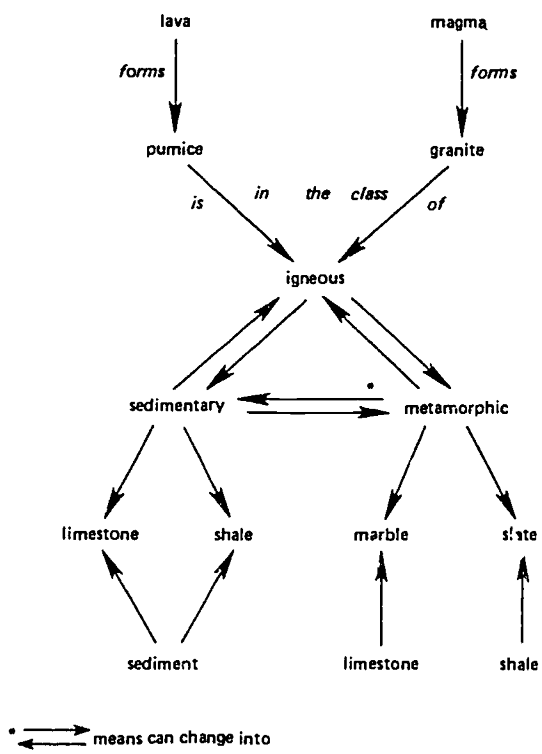
The paragraphs you've just read basically describe how people are asked to structure concepts in the ConSAT. We developed the ConSAT as part of our research into science learning. Some of the students participating in our research were in a junior high school science class in a city school. They were studying physical geology and used an instructional module dealing with minerals and rocks, from the Lyell Unit of the Individualized Science program. (Note 1) We administered the same ConSAT tasks (which used terms like those in the last example, above) before and after the students studied the instructional module. The ConSAT tasks were used as a measure of achievement--specifically the extent to which the students had learned some of the principles that geologists use to organize geological knowledge. For each ConSAT task, the students were asked to arrange the "words-I-know" pile on a large piece of paper to show how they thought about the words. While completing the arrangement, or after its completion, each student was asked to tell why the terms were arranged in this manner. As the student pointed out relationships between the words, we connected the related words or groups of words with a line, and then labeled the line with the relationship which the student reported. We also asked questions about further relationships or connections that the student may have understood but had not verbalized. At times the student changed a term from one position to another. We encouraged this and asked questions about the change, while noting the lines and relationships. At the end of the task, we knew the meanings that students attributed to geology terms, what they could show about the relationships between the terms, what terms and relationships needed to be clarified or retaught, and how, by using this structuring technique, they might be taught.

The simplicity of the ConSAT task masks some of the complexity involved in choosing the terms to be organized by the students. We should give you some idea how we did this. The instructional module on minerals and rocks was designed intentionally to incorporate structural features of the discipline of physical geology, structural features you would expect to find in the writings of geology experts. The key concepts of the module can be incorporated into two basic types of structures--hierarchical class-inclusion and transformational.

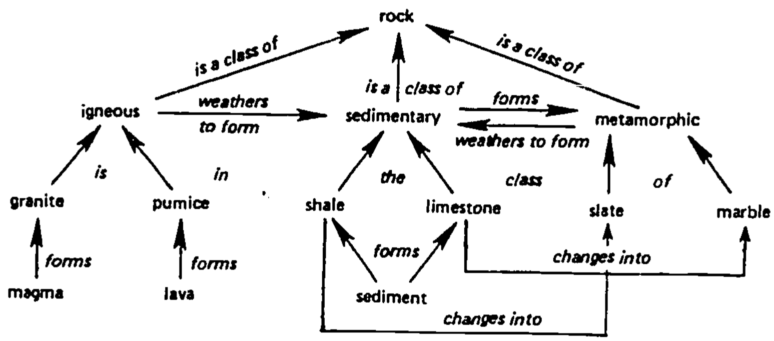
The classification of rocks in the hierarchical class-inclusion structure is represented by the diagram shown below:



Also, the terms and relationships of the rock cycle in the transi..rmational structure can be represented in a composite diag.am, as shown below.



Up to this point, the hierarchical class-inclusion relations of the terms and their transformational relations have been considered separately. However, the two kinds of structural relations can be integrated into a single representation.



It was this integrated structural representation which we used as a standard for judging the students' representations. We looked to see how many of the crucial attributes present in the integrated structure were also present in the structures that the students made. The chart below shows the classes of structural representations we used in analyzing the students' structures. (In the classroom you probably won't want to use such a stratified scheme. The questions suggested at the end of the Assessment and Evaluation section might be more appropriate.)

CLASSES OF STRUCTURES

CLASS	ATTRIBUTES OF THE CLASS
W-6	integration of hierarchical structure and transformational structure into a single structure
W-5	hierarchical structure plus fragment of transformational structure
W-4	hierarchical structure or transformational structure
W-3	fragments of the hierarchical and/or transformational structures
W-2	two or more words related by a single technical or general usage label

CLASS	ATTRIBUTES OF THE CLASS
W-1	two or more words, unspecified relationships
G	two or more words related by a single morphological characteristic

An important feature of the integrated structure is its parsimony. There are other possible relations that might be added, but they add no meaning to the structure. We should also note that there are other factors influencing the choice of concepts for the ConSAT tasks, including the teacher's estimation of the importance of the concepts, the structural organization of the instructional materials, and the number and scope of concepts that the teacher judges the students can manage.

ConSAT for Teachers

As we discussed above, the philosophical notion of discipline structure and the psychological notion of knowledge structure are central to many issues in curriculum development and instruction, but neither one of these notions is systematically applied directly to teaching methods. The ConSAT offers you both a way to use the notion of discipline structure as a basis for presenting your material and a way to analyze the organization of concepts by making a structural representation of them.

Teacher-Student Interaction

During the development and research stages, the use of the ConSAT was discussed with people in the following university situations: a class for science education student teachers; a conference of reading specialists; a seminar in educational consulting; a class in middle-school curriculum development; and a class in curriculum analysis. The teachers we talked with felt that one of the most intriguing aspects of the ConSAT was the emphasis on the student/teacher relationship. The students have a chance to explain how they are thinking, both verbally and with the use of props. On the other hand, the teacher, through probing at particular points, can raise issues, ask questions, and observe how the student is relating concepts. If this is contrasted with the more usual procedures of asking questions and receiving answers, it seems clear that the types of questions asked by both students and teachers are much different here. For example, a usual question during classroom discussion might be, "What are the three main classes of rocks?" Students who have memorized and can give back the answers "igneous, sedimentary, and metamorphic," are said to have the correct answer. When the ConSAT tasks are given, however, it is easily observed whether the student knows the answer to that question by the way these terms are related and structured.

Students and teachers can also call upon other students and teachers to share and discuss their ConSAT tasks. The ConSAT could be used for discussions either between the teacher and small groups or by the whole class. This may be particularly instructive for showing students how the teacher structures a group of concepts. For example, before presenting a lecture, the teacher might put a list of important terms on the board, and, afterward, ask the students to structure the terms as they had been organized in the lecture. The teacher could then put a representation of the lecture structure on the board as a standard for comparison. Similarly, individual students might discuss their structures with other individuals, small groups, or the whole class. For example, a small group of students might be given the assignment to structure the important terms in a biology textbooks's chapter on cells to be presented to the class as a re-view. In this case, the teacher would generate questions about the quality of the structure being presented.

Assessment and Evaluation

If, for assessment purposes, the teacher chooses concepts for the students to structure before the course begins, this alerts the students to the key terms to be used during instruction. Further, it encourages the teacher and the students to evaluate what the students already know. You have no doubt discovered that sometimes what you teach students is not new concepts or new ideas, but new ways of structuring those concepts.

For example, before instruction in classical mechanics, the teacher might write on the board such important concepts as mass, volume, speed, acceleration, force, energy--and ask the students to set aside the concepts they do not know and to structure the remaining concepts to show how they think about them, including the relationshps between concepts. Almost all of these terms are familiar ones that students already use in daily life and can relate to each other in some way. But, since these terms have a special, more constrained meaning in classical mechanics, and in some cases a different structural relationship from the one in common usage, the students will first have to change their preconceptions of these terms in order to fully comprehend the instruction. By becoming familiar with the students' preconceptions or lack of knowledge about key terms, as demonstrated by the ConSAT tasks, the teacher will know where to begin instruction--by clarifying how these terms are defined and related in daily life compared to their relationships in mechanics, and then by building new concepts from there.

If the students' pre-instructional structures are saved, they can then be compared with those from the same ConSAT task done at the end of an instructional sequence. This can help the students and teacher evaluate the changes brought about by the instruction.

Depending on the concepts and the subject matter, you might look for some of the following during the assessment and/or evaluation exercises: (1) Do students connect the concepts in an integrated fashion? (2) By what criteria do students group concepts? (3) What relationships do students use to link concepts? (4) Are these relationships idiosyncratic or do they conform to relationships specified by subject matter specialists?

ConSAT for Reading and Writing in the Science Classroom

Up to this point, we have been applying the ConSAT to the design and assessment of science instruction. The ConSAT is also a useful mechanism for guiding students through the analysis of difficult science text.

Suppose you were to ask a class of high school students to read the passage on the following page. The organization of this passage is based on a comparison between two logical systems that explain motion, one set forth by Aristotle, the other by Newton. As stated in the passage, each system postulates a relationship between motion and force. The assumed relationship between force and motion in each case can be represented in the following manner:

A most fundamental problem, for thousands of years wholly obscured by its complications, is that of motion. All those motions we observe in nature, that of a stone thrown into the air, a ship sailing the sea, a cart pushed along the street, are in reality very intricate. To understand these phenomena it is wise to begin with the simplest possible cases, and proceed gradually to the more complicated ones. Consider a body at rest, where there is no motion at all. To change the position of such a body it is necessary to exert some influence upon it, to push it or lift it, or let other bodies, such as horses or steam engines, act upon it. Our intuitive idea is that motion is connected with the acts of pushing, lifting or pulling. Repeated experience would make us risk the further statement that we must push harder if we wish to move the body faster. It seems natural to conclude that the stronger the action exerted on a body, the greater will be its speed. A four-horse carriage goes faster than a carriage drawn hy only two horses. Intuition thus tells us that speed is essentially connected with action.

It is a familiar fact to readers of detective fiction that a false clew muddles the story and postpones the solution. The method of reasoning dictated by intuition was wrong and led to false ideas of motion which were held for centuries. Aristotle's great authority throughout Europe was perhaps the chief reason for the long belief in this intuitive idea. We read in the *Mechanics*, for two thousand years attributed to him:

The moving body comes to a standstill when the force which pushes it along can no longer so act as to push it.

The discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought, and marks the real beginning of physics. This discovery taught us that intuitive conclusions based on immediate observation are not always to be trusted, for they sometimes lead to the wrong clews.

But where does intuition go wrong? Can it possibly be wrong to say that a carriage drawn hy four horses must travel faster than one drawn hy only two?

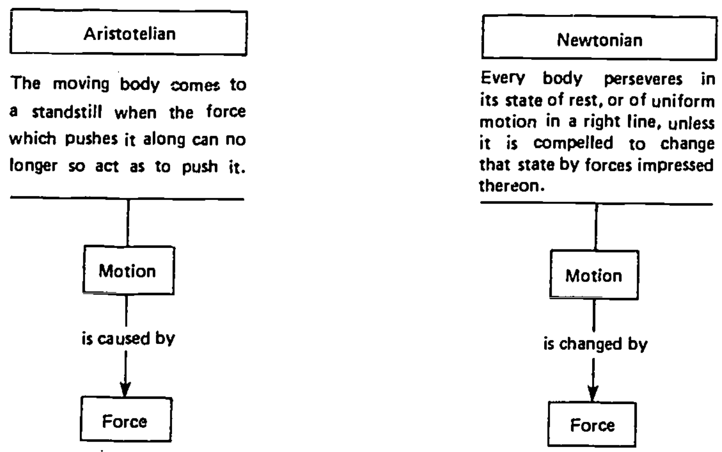
Let us examine the fundamental facts of motion more closely, starting with simple everyday experiences familiar to mankind since the beginning of civilisation and gained in the hard struggle for existence.

Suppose that someone going along a level road with a pushcart suddenly stops pushing. The cart will go on moving for a short distance before coming to rest. We ask: how is it possible to increase this distance? There are various ways, such as oiling the wheels, and making the road very smooth. The more easily the wheels turn, and the smoother the road, the longer the cart will go on moving. And just what has been done by the oiling and smoothing? Only this: the external influences have been made smaller. The effect of what is called friction has been dimenished, both in the wheels and between the wheels and the road. This is already a theoretical interpretation of the observable evidence, and interpretation which is, in fact, arbitrary. One significant step further and we shall have the right clew. Imagine a road perfectly smooth, and wheels with no friction at all. Then there would be nothing to stop the cart, so that it would run forever. This conclusion is reached only by thinking of an idealized experiment, which can never be actually performed, since it is impossible to eleminate all external influences. The idealized experiment shows the clew which really formed the foundation of the mechanics of motion.

Comparing the two methods of approaching the problem we can say: the intuitive idea is– the greater the action the greater the velocity. Thus the velocity shows whether or not external forces are acting on a body. The new clew found by Galileo is: if a body is neither pushed, pulled, nor acted on in any other way, or, more briefly, if no external forces act on a body, it moves uniformly, that is, always with the same velocity along a straight line. Thus, the velocity does not show whether or not external forces are acting on a body. Galileo's conclusion, the correct one, was formulated a generation later hy Newton as the *law of inertia*. It is usually the first thing ahout physics which we learn hy heart in school, and some of us may remember it:

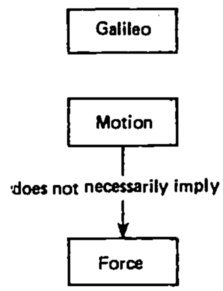
Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state hy forces impressed thereon.

From: Albert Einstein and Leopold Infeld, *The Evolution of Physics*, New York, Simon and Schuster, 1938.

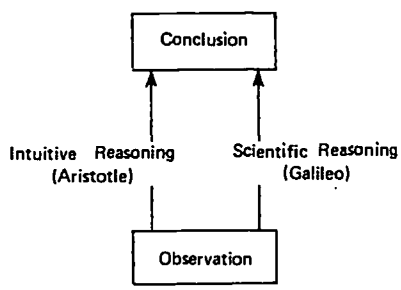


With this structure in mind, you can use the ConSAT to help your students comprehend the passage. Central to their comprehension will be their understanding of the difference between the Newtonian and Aristotelian assumptions about motion-- a difference made obvious by the above representation. Aristotle's assumption was based on his observations of real carts; Newton's was based on an idealized cart on an idealized road. Aristotle's approach was intuitive, Newton's idealized.

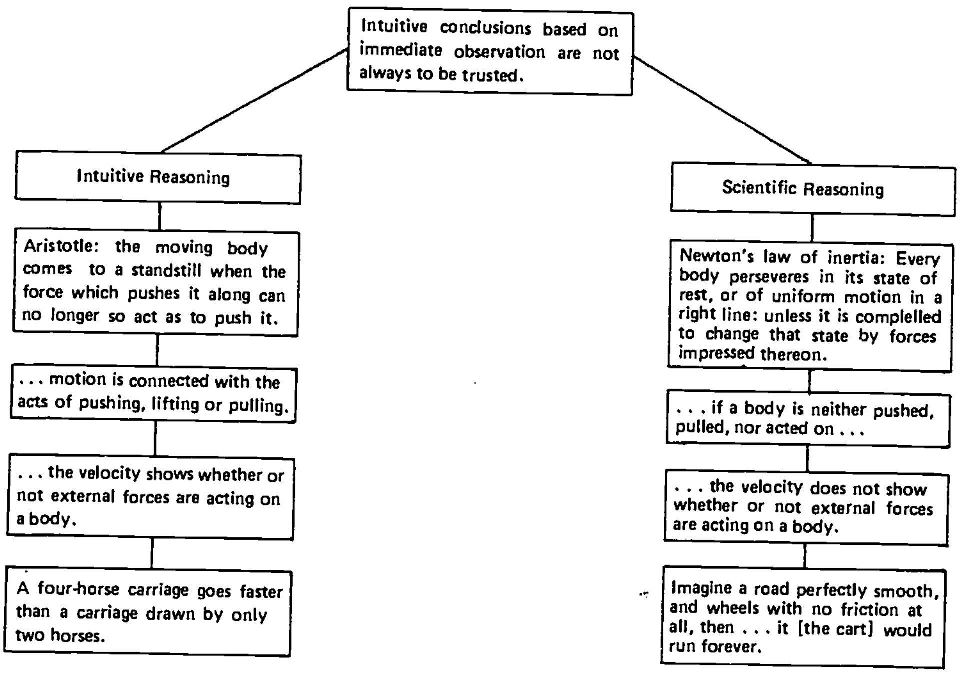
There is a more basic point to be made about this passage. This can be understood by looking at the nature of Galileo's contribution to the discussion, which indicates an historical change in direction of thinking about motion. Galileo did not trust the Aristotelian intuition that simply because force and motion are associated in our experience, we should conclude that there can be no motion without force. Galileo asserted that it is possible for a body to move even when no force acts upon it. Looking at the reading passage, we can represent Galileo's contribution this way:



This important change in the thinking process, basically a change from intuitive reasoning to what is today called scientific reasoning, was a major contribution toward the development of classical mechanics. Using a ConSAT-type representation, we can diagram the two kinds of reasoning like this:



The authors' big message in this passage, then, is that "intuitive conclusions based on immediate observation are not always to be trusted." They make their point by contrasting Aristotle's and Newton's logical systems about motion. Using the ConSAT to structure the concepts as they are stated in the reading passage, you can now put together a total picture something like this:



By applying the ConSAT to this reading passage and working it out with the students, you are helping the students build their analytical skills. In addition you are highlighting a key principle of physics, using a technique that is highly pictorial and concrete, and allows for maximum interchange between you and the students. You might also want to point out that the coherence and simplicity of the structure built from the passage shows the authors' skill in treating a difficult subject in mechanics with masterful logical control and great clarity in language.

During your discussions with the students, you would probably find some who make no structural representation at all, who cannot pick out the major theme or see the relationships between concepts. Some students might build a structure based on a scheme that accords with their own concepts of motion, rather than the authors'. It is to be expected that most students without prior knowledge of physics would have the Aristotelian rather than the Newtonian view of motion and, therefore, might be confused by the passage and fail to see its point. The confusion will show up in the structures they draw and in their explanations for why they drew them that way. Any of these idiosyncratic structures that the students turn in to you would indicate what you need to do to help them clear up the confusion and develop the skill to reproduce the logical structure of a passage. The ConSAT task provides a method for making explicit to the students both the structure of the passage and the structure of their own knowledge. The final product is not as important as the process the students go through. Students would also profit from making their own choices of concepts from a passage, particularly after they have developed some skill in this task.

The analytical process involved in using the ConSAT for analysis of science text is similar to that for teaching students to write responses to essay questions. The students would be encouraged to identify the major ideas they will write about and then to construct a diagram of these ideas which shows how they relate to each other. In this case, the students are creating structures from concepts they themselves have generated from prior knowledge about the subject.

Let's look at a standard physics problem that you might use to demonstrate to students how the ConSAT can help them compose a solution in a well-written paragraph. Suppose that you present the following problem to a high school physics class:

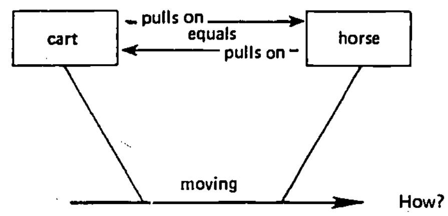
> A horse pulls a cart along a road. The cart exerts a force on the horse that is equal and opposite to the force the

> horse exerts on the cart. Explain how it is possible for the horse to move the cart. Give your answer in a clearly-written paragraph. Use diagrams.

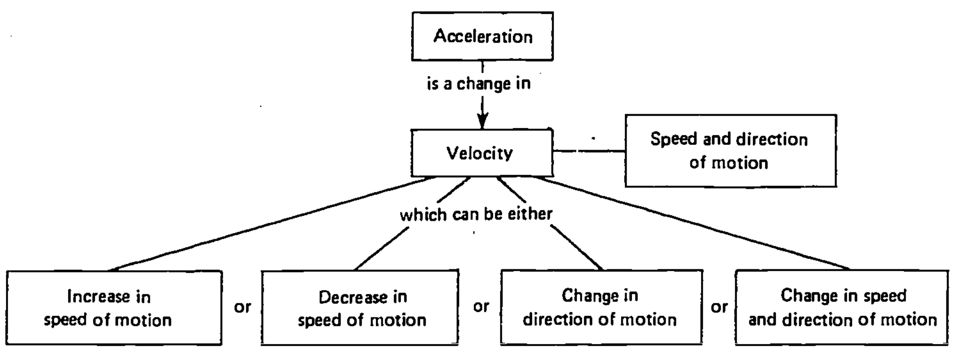
This problem is given to physics students to test if they understand the proper applications of Newton's Laws. The laws are stated below:

> First Law: Every material body persists in its state of rest or of uniform (unaccelerated) motion in a straight line if and only if it is not acted upon by a net (*i.e.*, unbalanced) external force. (Holton & Roller, 1958, p. 61)
>
> Second Law: The net (*i.e.*, unbalanced) external force acting on a material object is directly and linearly proportional to, and in the same direction as, the acceleration of the object. (p. 63)
>
> Third Law: In the interaction of any two objects--whether this interaction be by contact, by gravitational or electrical or magnetic means, or in any manner whatsoever--the first object exerts a force on the second and, at the same time, the second exerts a force on the first; these two forces have the same magnitudes but opposite directions. (p. 82)

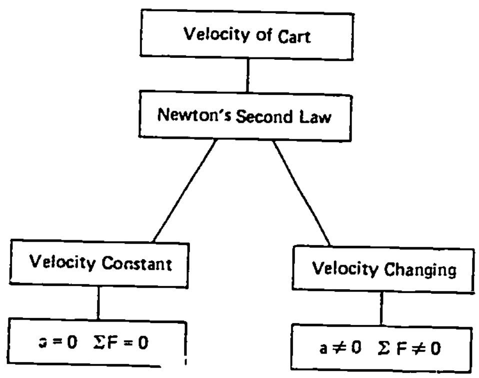
The problem we are dealing with here states that the cart pulls on the horse with a force equal and opposite to the force of the horse on the cart, a true instance of the Third Law. The question, however, is about the cause of the cart's motion. The Third Law does not address the question of cause of motion. Therefore, the Second Law should be applied because it addresses the relationship between force and motion--in particular, acceleration. Now that we've chosen the appropriate law, we should begin by drawing a diagram of the problem and by defining some basic terms. The question is represented in the following way:



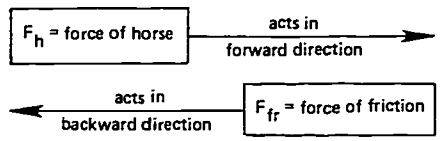
To apply the Second Law to this situation, we need to know about acceleration, which is defined in physics as a change in velocity, which, in turn, refers to the speed and direction of motion. The relationship between acceleration, velocity, and speed can be represented like this:

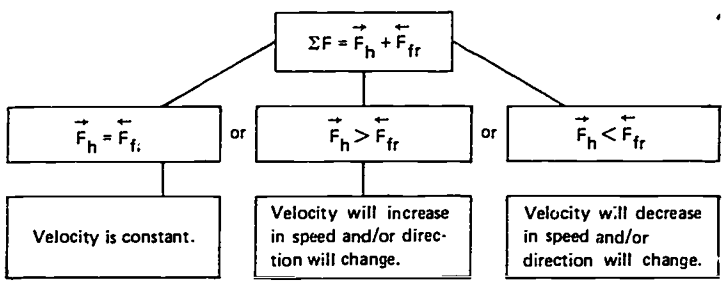


When we return to the problem, we first ask what it tells us about the cart's motion. We are told that the cart is moving, so we can conclude that the cart's velocity is not zero. One of two possibilities describes the velocity of the cart. It may be constant, in which case there is no acceleration, or it may be changing, in which case the cart is being accelerated. In the first case, where the velocity is constant and therefore the acceleration is zero, the Second Law states that the sum of the forces on the cart is zero. In the second case, where the velocity is changing and therefore the acceleration is different from zero, the sum of the forces on the cart must be different from zero. A diagram of these two possibile cases for the velocity of the cart would look like this:

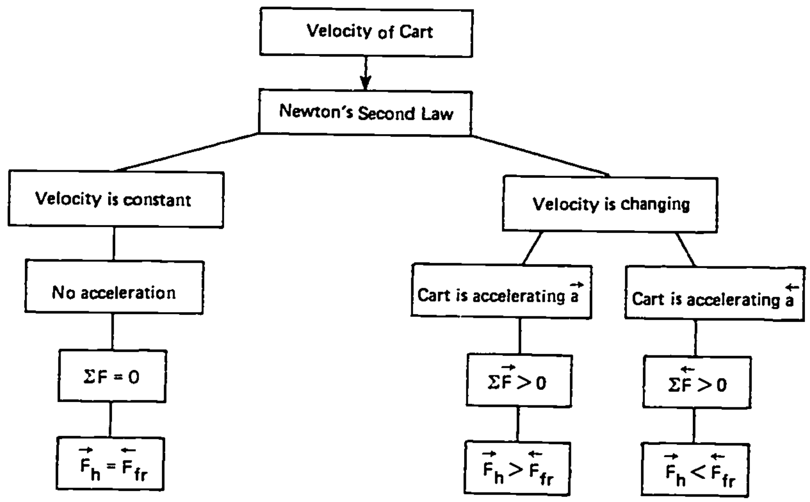


Now let's think about the forces on the cart. There are two forces, in the horizontal direction, on the cart: (1) the pulling force of the horse; and (2) the force of friction, which is opposite in direction to the pull of the horse. Using the left side of the above diagram showing the two possible cases for the velocity of the cart, the velocity will be constant if the force the horse exerts is equal in magnitude to the force of friction ($\Sigma F = 0$). Using the right side of the above diagram, the velocity of the cart will increase in speed or/and the direction of the cart will change if the force of the horse on the cart is greater than the force of friction ($\Sigma F \neq 0$, $F_h > F_{fr}$). Also, the velocity of the cart will decrease in speed or/and the direction of the cart will change if the force the horse exerts on the cart is less than the force of friction ($\Sigma F \neq 0$, $F_h < F_{fr}$). We can set up these three possibilities in a diagram like this:





If we now put together what we know about the velocity of the cart, the forces acting on it, and the relationship between force and acceleration as described by the Second Law, we can draw conclusions about how the cart is moving. If the pull of the horse is equal to the force of friction on the cart, the velocity of the cart is constant and there is no acceleration. If the pull of the horse is greater than the force of friction on the cart, the velocity of the cart is increasing in speed or/and changing in direction and the cart is accelerating. If the pull of the horse is less than the force of friction on the cart, the velocity of the cart is decreasing in speed or/and changing in direction and the cart is accelerating. A diagram can say this succinctly:



In working out the solution to this problem the teacher is presenting some basic concepts of classical mechanics in a diagrammatic step-by-step process, taking the students through the logical procedure for solving a physics problem, and giving them a method of structuring an analytical paragraph that has a logical sequence and clear relationship of ideas. In setting up this structure as an example for building composing skills in science, the teacher will have several basic points to make to the students:

<u>Content</u>:

1. Make clear to the students why the Second Law applies to this problem rather than the Third. Show why the Third Law is inappropriate.

2. Work through with the students how a general law can be applied in specific instances.

3. Discuss and clear up misconceptions about concepts that arise from discussions with the students about the structure.

Form:

1. Urge students to analyze the structures for logical coherency and concise expression. (They will need considerable help on this. The interactive nature of the ConSAT can contribute a great deal to the process.)

2. Have students look closely to see that relationships between concepts are clearly and correctly indicated in the structure.

3. Ask students to compose a paragraph based on the structure keeping in mind that the writing should be as clear, concise, and accurate as possible. If the structure has been modeled according to the above points, the results should approach the ideal stated here. (The Einstein-Infeld passage in the preceding section is an excellent model.)

After some practice with this problem, the students should be ready to try working out their own solutions using the ConSAT-type of structures demonstrated here.

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Conclusion

We have tried to show that the ConSAT has practical, direct applications in the classroom. First, it is a relatively quick and simple procedure that allows you to assess your students' understanding of concepts. The amount and richness of the information a teacher can obtain from analyzing a ConSAT task is quite different from the assessment provided by multiple-choice items or essay tests. The ConSAT emphasizes "looking into" what and how a student is thinking. Further, concepts and structure are presented visually, responding to the needs of those learners who prefer concrete props.

Secondly, the ConSAT promotes discussion between the teacher and the students. By cueing the students to the important relationships through their physical manipulation of key terms, the ConSAT tasks make it easier for the students to talk about and reveal the structural characteristics of their knowledge. Thirdly, the nature of the ConSAT emphasizes that there is no one best way to structure information. Through the ConSAT tasks, the students represent their perceptions of the concepts and relationships. This is an ideal place to begin instruction. Although a "standard structure" may be available, it is still possible to construct a variety of idiosyncratic structures that have validity for the individual learner. Further, the students can easily modify their structures. This feature of the ConSAT reinforces the idea that knowledge can be structured in many ways, none of which is timeless.

Additionally, changes in a student's structural representations from pre- to post-instructional ConSAT tasks are at times dramatic, providing concrete evidence of the student's growth of knowledge and the ability to structure. Lastly, the ConSAT provides students with opportunities to integrate and synthesize knowledge and to do this in a personal relationship with the teacher.

Footnote

1. Individualized Science (IS) is a basal science program intended for use in school grades K through 8, and consists of a complete science curriculum integrated with an individualized learning management system (Champagne and Klopfer, 1974). The IS program encourages open-ended student investigations and is designed to enable the child to acquire a foundation of scientific literacy and to become skillful in using the processes of scientific inquiry. One way in which this is done is through the use of an instructional resource called "Invitation to Explore" (ITE). A series of these ITE's appears in certain instructional units of the IS program. However, most of the ITE's can be used independently of the IS program's unit; in that case the ITE functions as a self-contained instructional module.

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