DOCUMENT RESUME

ED 404 136 . SE 054 976

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TITLE Teaching for Thinking in Senior High Science.
PUB DATE 21 Aug 94
NOTE 40p.
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Classroom Research; *Communication Skills; Foreign Countries; *High Schools; *Portfolios (Background Materials); Science Activities; Science Education; *Science Projects; Scientific Concepts; *Writing Assignments
IDENTIFIERS Alberta

ABSTRACT

Today's curricula must incorporate activities that help students make science concepts and skills their own. Many suggest that teachers should allow students to relate classroom lessons to their own lives, explore a wide variety of applications and connections to other knowledge and experience, and consolidate the learning in ways they will remember. This document suggests that teachers can better achieve these goals by helping students to enhance their communication skills which includes reading, writing, speaking, listening, and viewing. A variety of activity ideas that focus on using these communication processes are presented. The specific intent of this paper is to help teachers incorporate the use of three important assignments in the senior high science program. Discussed are: (1) the science learning log; (2) the portfolio; and (3) the project. (ZWH)

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Teaching Strategies: Language for Thinking and Communication

Teachers know that students do not simply absorb new concepts by listening to someone explain them. Students must internalize science concepts and skills by learning to use their own communication processes -- (1) reading, (2) writing, (3) speaking, (4) listening, and (5) viewing. This paper presents a variety of activity ideas that focus on using these five communication processes. The goal of the paper is to help teachers incorporate the use of three important assignments in the senior high science program. These three assignments are:

1. The Science Learning Log
2. The Portfolio
3. The Project

The communication activities in these three assignments can help students make science concepts and skills their "own" by relating them to their own lives, exploring a wide variety of applications and connections to other knowledge and experience, and consolidating the learning in ways they will remember.

Using these communication activities can also save teachers time. The use of these activities allow teachers to helping themselves and their students quickly pinpoint their learning difficulties and find strategies to overcome them. Teachers will also become more effective in their attempts to contribute to students' development of better reading and writing and discussing/presenting skills. These skills, in turn, yield rewards when teachers need to rely on such skills in science classes. Imagine teachers getting handed stacks of lab reports that they can actually enjoy reading, or conducting a lesson based on a text chapter that everyone has actually understood on their own!

Writing to Learn

Writing can meet students' need to process new learning, to "chew" it through, and to make meaning of it for themselves. Writing to learn requires that students need time and space to link the new concepts teachers are presenting to their past experiences and to things they already understand. As students begin to think their way through a new concept, they are often swimming in a whirlpool of mental associations, bits of information, half-formed questions, and a variety of feelings as they try to make sense of the new learning and place it somewhere in their current picture of reality. When teachers pause in their teaching and give students time to reflect and write about all the things running through their heads, students can internalize the new learning and connect it to stuff they already know.

This kind of reflection happens in quick periods of writing produced not for grading, but for students' personal use as they sort through their thoughts on paper. Such writing is not for an audience, so logic and polish and surface considerations like spelling are mostly irrelevant. The emphasis on writing to learn is writing as a *means* to an end -- the end being the formation of a new idea in the head. When students are writing to learn, it should be made clear that the written product is *not* an end in itself. It is not created to be handed in and graded.[1]

Four factors make writing effective as a means of learning:

(1) *Writing is permanent.*. It captures fleeting thoughts and helps students to hold onto an idea long enough to work it out before it vanishes. People remember ideas they have worked with in new varying ways through writing, such as translating the learning to other situations and mediums.

(2) *Writing is explicit.* . A student is forced to clarify and focus what is sometimes a tangle of thoughts as soon as she/he tries to put it into words. When we feel mentally blocked in our problem-solving, writing is a way to get unstuck. As we write, we often discover and

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[1]Obviously there is an important place in science instruction for writing polished into clear, concise prose intended for grading - more about this later.

crystallize shapeless ideas stored away that we'd forgotten about, and can watch connections unfold in front of us.

(3) *Writing is active.* When students write, they are actively representing ideas in symbols rather than just passively listening. Students usually remember best when they have constructed and written meanings for themselves. For this reason, most good teachers do not waste time asking students to simply copy notes. Instead, students must draw on relevant knowledge, review and consolidate the meaning, extend the meaning into other applications, then later reformulate and review the concept in light of new concepts presented. It is not enough for the teacher to review and consolidate the learning for the students; they've got to do it for themselves.

(4) *Writing requires organization.* To render ideas into language, writers must relate the parts of the idea in some meaningful way. Thought is multi-dimensional, reflecting endless configurations that sometimes leave the learner hopelessly mired. Writing, by contrast, is more linear. Words string into sentences, winding a trail that lends logical order to the spinning wheels of thought.

(5) *Writing connects to the self.* For many, learning means constantly seeking connection between the self and the rest of the world. People remember most things that are tied into their experience. These ties are often emotional memories, or images, or stories. These aspects of experience are more real to students than abstractions: storytelling, imagination, and feelings are the "human"

ways of knowing that students have relied on intuitively since birth. When students write spontaneously about memories sparked by new learnings in science, or generate poems connecting concrete associations and feelings with abstract science concepts and issues, or invent stories applying science concepts or skills, or write dialogues arguing two sides of a science/technology/society issue, the learning becomes memorable.

Activity One: Spontaneous writing

Spontaneous writing is simply spontaneous nonstop writing for a short period of time, say five to ten minutes. What flows out onto the page is a kind of "mental dump." The writer suspends critical judgment of the writing produced. Spontaneous writing is not the time to worry about sentence structure or word choice or tone. In some classes spontaneous writing becomes part of a *journal* or a *learning log* kept over a period of time. In others, spontaneous writing is just done at the teacher's directive on a clean page amongst other science notes. The product of spontaneous writing is not what's important (spontaneous writing often resembles “verbal soup” anyway). The thinking process that occurs (constructing, connecting, clarifying, consolidating meaning) when students write out their ideas at crucial learning times is the goal of spontaneous writing.

Students can write spontaneously in response to a teacher's specific question, or to reflect on what they've just learned, or to recall the process they used to solve a problem, or to generate questions, or to explore personal associations, or to brainstorm applications, or to sort out their opinion on an issue, or to complete any number of other writing-to-learn purposes in science.

Some students will have trouble when they are first asked to use spontaneous writing in class. Somewhere in their growth as writers they've learned to fear and resist writing as an agonized labor squeezing out an orderly succession of words that must be grammatically correct, spelled right and punctuated properly. Past writing "failures" have taught them to distrust their own writing. In short, they become paralyzed. Other students like to compartmentalize their learning. They are confused and uncomfortable when teachers try to make links between subject areas ("this is science class so why are we doing language arts?")

These students, like many adults who fear and resist new things, have to be nudged along until they discover the value of what they're doing. Students need to see models of student spontaneous writing, perhaps on the overhead projector. They need to be shown unique insights, asked tough questions, and encouraged by teachers who make seemingly "radical" connections uncovered through their spontaneous writing.

Teachers need to be explicit. Students need to be shown, with examples, how these writing exercises can actually help them learn and remember science concepts and skills. Teachers also need to be patient, remaining positive and accepting their first attempts.

Activity Two: Summarizing a Concept

After "teaching" a concept (whether through lecture, demonstration, text reading, or other method), teachers need to stop the class and have students write about what they have learned. Teachers may begin the activity by saying something like:

"Okay everybody, without saying a word to your neighbor, without asking a single question, without stopping to think, start writing an explanation of concept X as you understand it. Use your own words. Make it so clear that someone in this class could read it and understand it. Don't worry about spelling or sentence structure or repetition. Worry only about writing as clear an explanation as you can."

Teachers can then walk around the room while students write. At a glance it is obvious who understands the concept and who doesn't. More important, students will quickly come to realize just how comfortable they are with the new learning.

There are a number of variations to this activity. For example, teachers might have students exchange their "explanation" with a partner, read each other's, then respond to it orally or in writing. Some questions might include: did it work? was it clear? was it accurate? Teachers can try having selected students share their written summaries. If teachers give lots of positive encouragement and honest praise, they will encourage future spontaneous writing attempts. Or, teachers might try asking the students pretend they are writing an explanation for a younger sibling, or a junior high student, or some other audience. It is possible to ask students to develop, in writing, an example showing the concept in actions Students would then describe the concept through the example.

Activity Three: Using Learning Logs

Some teachers have students write a brief spontaneous writing summary in the last five minutes of each class. They then ask students to keep these summaries separately as "learning logs." Exercises like these help students recall and consolidate the learning of the day. Teachers might try giving students focus questions at first to get them started, such as: (1) What do you know now that you didn't know when you walked in today? (2) How can this new knowledge/skill help you in your own life? (3) What further question(s) do you still have at this point?

Activity Four: Using Personal Responses

After a lesson or a series of lessons about a particular concept/ skill, teachers can ask students to simply write spontaneously a one-page letter to them about what they are learning. If teachers like, they can provide prompts like the following for students who don't know what to write about. Often teachers write these prompts on a chart and post it somewhere in the room for students to glance at when writing a lesson response:

- What part are you finding easiest to learn?

- What parts did you already know, or had figured out in your own life?

- What part is still confusing for you?

- What one thing did you find out that you didn't know before that is really interesting?

- How do you feel right now about what we're doing?

- What part do you find is meaningful in your life somehow? How does it relate?

- Does any part relate to what you're learning now in another subject area? What's the connection?

- What questions have occurred to you (general or specific, related to the material or not) that we haven't addressed?

Personal responses also work really well when the class is discussing a science-technology/society issue. If teachers are using personal responses to teach students, they might ask students to stop everything (especially at points where the discussion is particularly heated and certain students who need longer thinking time before offering their opinion are not participating) and have students write spontaneously what they are thinking. In setting these up, they can ask students to address the following points: the points they agree/disagree with and the examples in the world they can think of. Or teachers can have their students suddenly write about the issue from a totally different perspective. For example, in the midst of a discussion on deforestation of Vancouver Island, students can be asked to assume the role of a representative from MacMillan-Bloedel who has been listening to the class remarks so far. From this perspective, the students can then write the thoughts and feelings of that person about the issue in a spontaneous fashion.

The important thing for teachers to remember is to encourage personal response in open-ended writing. Teachers want to make sure that the activity does not degenerate into a list of questions that students must answer. What teachers are after is their honest responses to what's going on with them in their science learning. The activity of spontaneous writing is as much a chance for students to discover their own questions and link these questions with their past experiences and knowledge as it is for the teacher to get an immediate sense of how well the students are processing the information he or she is presenting and why some students are having difficulty.

Activity Five: Using Two-Column Notes

When using two-column notes, students should divide their note pages in two. On the left side they should keep informational notes throughout the lectures or text readings, just as they probably keep running notes now in their classes. In the right column they should write personal responses to the new material as described above. These personal responses can include questions, fleeting associations with personal experience and other knowledge, applications, frustrations, etc. During a class lecture teachers might want to stop now and then to allow students a few minutes to reflect on the new learning and write in the right column.

Activity Six: Using Responses in Dialogue

Using Responses in Dialogue is a simple activity. In this activity, students should write personal responses to a lecture or text reading. Their responses should be addressed to a specific partner, just like they were writing a "letter." They should then exchange this "letter" with their partner, who writes a response back to them. These responses allow the students to learn from their own writing as well as from each other.

Activity Seven: Problem-Solving in Writing

As students problem solve during their writing, they work to describe the process they went through in solving a specific problem immediately after they finish the problem -- even if they get stuck and can't solve the problem. The point here is to help students become aware of the *way* they found their way through the problem, then help them compare this to how others solved the problem so that they can re-assess the efficiency of their own problem-solving process.

The central question is: How can I improve my approach to a similar problem next time? Students can then share their solution process with a partner, or with a small group. Or, they might lead the class through a method they have learned that helps them solve the problem. Then the students can go back to their writing-about-their-solution-process, evaluate it, and write again -- this time about alternate approaches to the same problem, or elements they hadn't considered, or what they might do differently next time.

Activity Eight: Clustering (also called mindmapping, networking, and webbing)

When starting a unit, students should be given a key word or concept to "cluster." Cluster means jotting down any ideas or experiences they associate with that word. Students should write this word or phrase in the center of their page with a circle around it; they should then quickly jot down key words or phrases to represent things they associate with that root word. These associations form "branches," with one association leading to another until the train of thought is exhausted.

Then the writer begins again at the root word, starting a new branch of idea clusters. The clustering continues until an idea forms clearly enough for the student to want to start writing about it. At that point there is a shift -- the student quits making "idea branches" and actually starts to write about an idea which has encouraged the motivation to write. This shift is important, for it is the main purpose of the exercise.

This exercise helps students consolidate their background knowledge about a new area of learning. As students work out the branches, the teacher can see the constructions of their students' mental associations. As clustering moves into writing, the resulting process provides teachers an excellent way to help students focus and begin to explore the material that the teacher wants to present.

Evaluating Writing-to-Learn

As teachers increase their use of personal response-type writing in their classrooms, they often have to do something that makes students feel accountable or some just won't work. At least, they won't work until they find out how much fun writing can be. Teachers can try allowing in-class time for quickie free-writes. They can also give students set time limits -- five to seven minutes is usually lots of time -- and insist that there be NO talking during that time. In true spontaneous writing, teachers should insist that they write without stopping, without even taking their pencils off the page. If students run out of ideas they simply write "I don't know what to write" or their last word or phrase again and again until the juices start flowing again.

Teachers should not try to grade it or even read it all -- there just isn't time. Peers should read their partners' work as much as possible. Teachers can also have selected students share theirs for the class, finding some interesting ones themselves and displaying them on the overhead. Often these displays prompt the "cooler" students to get involved so they too can get into the spotlight. Sometimes classes absolutely must know that their work "counts for something." If this is the case, teachers can have their students keep all their spontaneous writing in a separate section or notebook and turn it all in periodically. At this time, teachers can flip through it, comment on the interesting bits, and assign a holistic grade.[2]

In the case of free writings that actually are letters to the teacher (containing students' questions, areas of confusion, and other valuable information), the teacher should try to have a few students go through these and make a list for the class of all the questions. Then both the teacher and the students can proceed to find the answers

[2]Refer to the sample marking key at the end of this chapter.

and fill in these "gaps" of knowledge.

The Writing Process Approach to Formal Writing

When students are preparing written reports, essays, or other formal writing for an audience, they cannot usually spin out clear, concise, well-organized, properly punctuated prose when they first set pen to paper. The expectation by some students that writing will happen easily is a frequent source of frustration -- because it usually does not. Writing is, in fact, a long and usually messy process. It varies remarkably for each individual, but the process often is generalized as follows:

Prewriting	Ideas percolate, are consolidated, and are clarified in the writer's mind. A purpose and audience for the writing is established. Initial planning occurs. This initial writing includes putting the writer's ideas into words and the words into some logical sequence. "Prewriting" happens in observation, discussions, thought, spontaneous writing, more thought, more writing, and so on. Prewriting usually continues after drafting has begun.
Drafting	The "writing out" of ideas begins. Usually a first draft is "revisited" once, twice, or many times as the writer reorganizes, rewords, deletes, and adds ideas to craft succeeding drafts.
Editing	When the content is "set" and the writer is pleased with the shape, clarity and order of the piece, details are attended to polish the writing: spelling, punctuation, grammar, usage, tone, format, etc.

Ideas for Helping Students Improve Formal Writing in Senior High Science

1. Allow students time in class to explore and shape their ideas for a formal report through talk, list-making, spontaneous writing, etc.

2. Encourage revision by asking to see first and second drafts attached to final report.

3. Allow time for revision in class: for instance, declare an early due date for first drafts, then have students work with partners or in small groups to read each other's piece and provide feedback. This process is called "conferencing" or "peer editing." Most students will have been taught what to do by their language arts teacher. Be sure to give students specific criteria and a structure for giving feedback.

4. Provide models of "good" student writing, perhaps using the overhead projector, to show students what you mean by clear descriptions of things observed, well-organized paragraphs, concise summaries, etc.

5. Try not to grade all formal reports, paragraphs, etc. For example, you can have students submit all finished pieces but you only choose certain ones to grade. Or have all students prepare a lab report but only select one from each lab pair to mark. Have students evaluate each other's writing. For example, small groups can assess a set of papers according to criteria you teach them. Finally, have students evaluate their own writing.

RAFTS Writing Assignments

The RAFTS formula (Role - Audience - Format - Topic - Strong Verb) creates imaginative writing exercises to help students adopt new perspectives on a science issue, discover divergent applications for a concept, or make sudden connections between themselves and their learning. To start, the teacher should decide the specific topic that will be the focus of the writing. Then, the teacher can make a list of possible "roles" the students could assume in discussing the particular science topic being worked on, and another list of potential "audiences" that their remarks might be directed to.

The teacher can help by choosing a role and audience for the exercise, or have your students choose their own. The next choice is a writing format for the students to use.[3] To create the RAFTS assignment, the teacher should write a sentence tying together the role, audience, format, and topic together with a "strong verb" identifying the main purpose of the writing. For example: As a (ROLE), write a (FORMAT) to (AUDIENCE), (STRONG VERB) ing about (TOPIC).

Teachers can use RAFTS assignments when they want to tempt students to make new mental connections, or explore elements and applications of a concept that they may not have thought of through "regular" question-answer channels. RAFTS can be used to make up quickie five- or ten- minute in-class writing exercises or to develop essay assignment topics. Students can also use the RAFTS formula to make up their own writing assignment. A pleasant side-effect of RAFTS assignments are the usually lively and interesting products.

Reading Strategies for Science Materials

Some students will not have many reading strategies to help them learn new science concepts through textual explanations. Some of the strategies include:

[3] The list at the back of this chapter can be a starting point.

Headlines	Divide material into chunks and form a headline to summarize the information in each chunk.
Outlines	Condense all the key ideas into a one-page outline, writing each as an appropriate heading.
Questions	Skim the material, then list all your questions about it. Read to find the answers to the questions.
Predicting	Skim titles, subheadings, pictures, graphics, opening and closing paragraphs, then predict the content. Before and during reading, stop periodically to list predictions and hypotheses about the information being presented. Compare these with others. Compare them to information revealed later in the text. Or, before reading, try writing everything spontaneously you know about the topic being presented and predict what new information you will learn.
Key Lines	Choose the most important lines. Justify and compare to others' choices.
Response	After reading, write spontaneously a personal response or write questions you have about the reading.
PQ4R	Quickly *preview* or skim the material, then list *questions* that occur based on this skimming, then *read*, *reflect*, *recite* by answering questions, and finally *review*.

Speaking/Listening

Through talk, just as through writing, students process their learning. As they talk they sort out and clarify their learning, test their hypotheses, become aware of their associations, make connections between the new ideas and their past experiences and knowledge, and extend their understandings. Because talk is so helpful as students are putting together their ideas for writing, teachers should provide many opportunities for small group discussion. Teacher-led discussion on occasion is valuable, but this approach severely limits the number of students who get a chance to verbally "chew through" the new concepts. Whole-group discussion is also not as "safe" a place as the small group to verbally work through half-formed ideas and ask questions.

Together We Learn (Prentice-Hall: 1990) is a senior high teacher resource describing many techniques for using collaborative small-group discussions. *Speak for Yourself*, (Nelson: 1990) also written especially for senior high language arts teachers, contains an abundance of activity ideas. A brief summary of ideas from these resources follows:

Role Play	Selected students in a discussion assume the point of view of a different person (i.e., in a small group debating an issue, each student might speak from the perspective of a different stakeholder)
Debate	Formal teams of two pairs, or informally in small groups. Students debate an issue posed as a resolution (i.e., be it resolved that fossil fuel consumption will be limited by household), using persuasive logic and researched support to present their opinions.
Jigsaw Groups	Example: each small "home" group is given a different article to read and make sense of (i.e., listing key points and author's overall position). Then one person from each "home" group is sent to join a new "composite" group, another person from each is sent to make up the second "composite" group, and so on. In the "composite" groups, members in turn teach their new group the article they studied in their home group.
Fishbowl	Informal small group discussion in the center of class, who observe and assess. Stop periodically for class reflection/analysis of what's happening, insights revealed, etc. Or, stop to substitute in a student from the observing group.
Seminar	Student "teaching" class through speech, slide-tape, display, dramatization, model, or other presentation of concepts learned.

Viewing

Viewing is considered a communication activity because humans must view to read and to comprehend the non-verbal messages crucial to oral exchange. With the explosion of media now being used in science classrooms, as well as in treatment of science issues in the world, critical viewing is an important skill to help students develop. One helpful approach to help students learn how to view better is to critically analyze the presentation of a science issue or concept on film or television, separating facts from opinions, examining method of presentation and selection of information, assessing use of entertainment factor to make science "palatable" for lay audience, the persuasive techniques used, etc.

Part of viewing is to see how things are put together. For example, teachers can work to help their students understand the forms that writing can take. Students can examine the visual presentation: the effects of sound, music, lighting, movement, special effects, camera angle, editing, color, angle, composition, line, and symbols to present phenomena in the natural world, or make a statement about a scientific issue.

Or, students might examine form in newspaper presentations. How is the eye directed to certain stories? What prominence is science given in overall context? How are science stories juxtaposed with others and with ads? What viewpoint is expressed editorially? And, what is the comparative frequency of science-issue editorials? How are headings and graphics, and other devices for simplifying the message, used?.

In all viewing, it's important to help students stand back critically from the viewed messages you bring into the classroom. Teachers can help mediate their response through discussion and guided reflection, prompting them to really *see* from different perspectives. Teachers can also help their students by spending time before each viewed presentation providing context and purposes for the viewing, and helping students to focus on certain elements. After viewing, students should be given time to write about their responses and observations, and to discuss and compare their responses and analyses with others.

Another aspect of "viewing" activities is actually creative construction. In other words, teachers could have students develop their own visual presentation of a concept, process, phenomena, or opinion on an issue. Possible forms for such a presentation include storyboards (i.e. a "blueprint" for a film that includes a series of drawings depicting the sequence of camera shots, with corresponding dialogue written underneath), comic strips, posters, advertisements, collages, photo-essays, computer graphics, displays, slide-tape presentations, video productions, board games, or bulletin boards.

Applying Communication Activities to Learning Processes in Senior High Science

The ideas presented here on using communication activities for science teaching has been based on a comprehensive theory called the "Diagnostic Learning and Communication Processes Program" (DLCP). What follows is a very brief summary of the main principles of the DLCP program in terms of specific instructional suggestions for science teachers.

Exploring

When beginning to learn a new concept, students ***explore*** the material by first becoming aware of their own relevant past experience. As they explore, they must risk failure and learning difficulty as they struggle to make connections between the new information and their previous knowledge, try to apply the new information even before fully understanding it, and ask the questions that will direct their search.

To help students explore in science, teachers can try the following communication activities:

(1) When introducing a new concept, have students list as fast as they can everything they know about that concept. Try having students then share their and consolidate their lists in groups. They're often surprised at the amount of knowledge they've already accumulated.

(2) Cluster a new concept or word to uncover their own associations and background knowledge.

(3) Brainstorm, alone on paper or in groups, all the questions students have about a new concept. (Quantity, not quality, is the key in brainstorming. Judgment of ideas must be suspended while students try to shake out ideas. In brainstorming, try having competitions for "the most ideas," and celebrate the most unique offerings).

(4) Write spontaneously predictions: experiment outcomes, chemical reactions, behavior of objects, based on previous knowledge.

(5) Write spontaneously personal response to the teacher after a lesson or a reading.

(6) Brainstorm possible applications for a new concept in their daily lives and the world around them. Or brainstorm possible new applications for a concept.

(7) Brainstorm examples in their personal experience of their new science learning. For example:

•*How many things can you think of in your personal experience where chemical changes occur? (After asking this question, have students choose one of these and explain in writing exactly what they think they chemical change is).*

•*In groups, list three chemical solutions you encounter in daily life. Figure out the properties of these solutions, relating what you know already about properties of electrolytes, non-electrolytes, acids and bases. Then find an interesting way to present your findings to the class.*

To evaluate how well your students are ***exploring,*** teachers can walk around the class listening to their group discussion or reading their spontaneous writing. The key indicators (shown here in boldface) are students' willingness to **risk failure, difficulty, dissonance;** the ease with which they **make connections and act on partial information;** and their ability to **ask questions to direct search for new information.** Teachers should notice that the emphasis is not on the PRODUCT they produce, whether it be a piece of writing or a group presentation, but the learning skills they demonstrate in the PROCESS of exploring.

Narrating

Story, or narration, is the most primal way of organizing and personalizing experience. When teachers allow students the opportunity to ***narrate*** as they are learning new concepts and skills, they can help their students connect their personal experience and other knowledge to new knowledge in a way they will remember. Narrative connects cognition with affect, which is why it's highly motivational; that's also why most good professional speakers rely on stories and anecdotes to get across their message. Teachers should try using the following communication activities to incorporate narrative using a scientific principle, phenomenon, force, element, or other thing being learned. The following examples suggest how narrative can be used:

(1) Write a mystery story where this thing is part of the key to the solution.

(2) Make up a love story in which the thing is a central character.

(3) Make up a "fractured fairy tale," adapting an old tale using scientific information they have learned.

(4) Tell a myth explaining how the thing you are studying came to exist. This can be an introduction to unit.

(5) Read a science fiction story and trace the extensions/expansion of known scientific concepts. (Check any literature anthology authorized for senior high language arts. Most contain at least one "sci-fi" story).

(6) Tell a science fiction or fantasy story showing a world where this thing is being used in ways thought impossible today.

(7) Make up a story about someone whose life was strongly affected by this thing.

(8) Choose a particular one of the thing (i.e. a particular fossil, or a particular glacier) and tell the story of this thing since it first existed, as if you were telling it to a six-year-old.

(9) Tell the story in a "rap" song for a twelve-year-old.

(10) As the thing, tell a part of your own story that no human has yet discovered.

(11) Tell the story of what happened during a real lab experiment, but change the ending, if you like (narrating the discovery process).

(12) Relate in writing, or in pairs/small groups, an anecdote from personal experience illustrating the science principles/skills being learned.

(13) Teacher: Read a story from which students must listen for information leading to learning a new science concept.

(14) Teacher: Introduce a unit with a story based on the science concept to be presented (i.e., a mystery story based on the use of a certain poison or acid.

Teachers can evaluate their students' use of the learning process of narrating. As they do so, teachers can check DLCP for checklists to help measure the extent to which the students connect their personal experience and other knowledge to new knowledge with anecdote; how well they use time and space to organize their narrations; and the amount they enjoy sharing their own and other's narrations.

Imagining

Imagination is the realm of creating new hypotheses, inventing new applications, and discovering new connections between forces and elements. Science students will only transcend the "what is" of the here-and-now when teachers prompt them to ***imagine*** "what might be." Concrete images are also more easily remembered than abstractions. The more teachers encourage students to transform new science concepts and skills in imaginative ways, the more successful and long-term their learning will be.

The following suggestions are given as examples for encouraging students to use imagination to expand their learning about scientific principles, phenomenon, force, elements, or other thing being taught:

(1) Compare the thing to something you are familiar with, and explain the comparison (this is called "writing similes"). For example: *A cell is like a ___________ because _________________. Possible Answer: A cell is like power: it reproduces like crazy , dies quickly, and can work for good or evil*
A cell is like a chicken: a totally autonomous living unit with no brains); or, A seismic wave is like a ______________ because __________________ .

(2) Imagine three ways this thing might be used, but isn't.

(3) If this thing were an animal, what animal would it be? (and why?)

(4) What person would it be?

(5) Picture this thing in your mind as if you are seeing it for the first time: what do you notice first?

(6) Imagine you are observing the outcome of a lab experiment you are about to perform. Describe in detail what you see.

(7) For an abstract concept, process, or set of relationships, imagine: what color it is, what shape, what place it is, what ecological system it could be thought as part of (what depends on it? what does it depend on? what does it eat? what eats it?)

(8) Examine a "new improved version" of an actual product recently released by a company. Imagining yourself as the competitor, design and test an even more improved version.

(9) Imagine you are a particular phenomena or thing (a chromosome in a 40-year-old female, the heart of dog, a rock from the Paleozoic era, a neutron in a nuclear weapon, etc.) tell your story. Use words or pictures or both (Create a play, story, collage, storyboard, comic strip, photo-essay, etc.)

(10) Use RAFTS to find different perspectives for viewing the thing:

(a) As an Amoebae to a , write a ing about . (b) As a tree, write a complaint to the Canfor pulp and paper mill about your treatment in the paper process

(c) As a specific compound to an assembly of students, write a speech warning about the hazardous effects you have on human health.

(11) Make up a case study based on a problem that the thing is creating. (Teachers may need to remind students that a case study describes a specific real-life issue by giving enough background and detail for problem-solvers to work with and by including brief portraits of the key players involved and their points of view.) Teachers may want to select the most interesting case studies produced and assign them to small groups of students to solve, or have various small groups each develop a solution independently to the same case study, then compare and debate their solutions.

When evaluating students' ability to imagine, teachers can utilize DLCP instruments to help students focus on their ability to use metaphor (comparisons), to create and transform mental images, and to imagine themselves in different times and places.

Empathizing

When students shift perspective from their own point of view to examine phenomena from other perspectives, they are often jolted into new understandings. Communication activities fostering this ***empathy*** with alternate points of view can help students achieve higher levels of awareness towards a "big picture vision" that will anchor their science learning into a larger pattern of meaning.

Following are some suggestions for situations to help students empathize with differing perspectives about a scientific principle, phenomenon, force, element, or other thing being taught. These situations can be topics for spontaneous writing or other forms of writing such as a letter, oral presentation, or a role play:

(1) Imagine you have been studying this thing for a long time. Write your journal entry explaining the latest thing you have learned about it or explain how you see this thing after a lifetime spent studying it.

(2) Create a mock public hearing in the classroom for an issue currently being debated by government. The teacher can identify various stakeholders ahead of time that students must research. Through role play, the students then present their position before the appointed committee.

(3) Imagine a time in the 19th century: you have just discovered this thing and are trying to convince the National Geographic to fund further research.

(4) Pretend you are a skeptical scientist in the 19th century who is attempting to disprove the discovery by your colleague of this thing.

(5) Imagine it is sometime in the 22nd century, when you as a scientist have just discovered that some understanding we have now about this thing is fundamentally wrong. Tell about your findings.

(6) Take a specific role in a current issue affecting health, technology, or the environment. For example:

As the mayor of Edmonton, write a reply to a citizen complaint about the foul taste of spring water, explaining the reasons for the taste.

DLCP instruments can help teachers evaluate students' ability to empathize, measure the extent to which they suspend judgment till full understanding reached, select language to take audience into account, take on other's role, or shift attention away from selves while communicating.

Abstracting

A major part of science learning is making and evaluating abstract generalizations, then applying these to make sense of new information or make predictions in new situations. Through the use of communication activities, students can refine their ability to ***abstract*** in a clear and logical way. Following are some examples:

(1) Write summaries (in own words) of new learning. Compare and discuss, then revise.

(2) Write predictions for a new concept, generalizing using information already learned.

(3) Create a graphic model to represent new learning.

(4) Create a cartoon to humorously personify an organism being studied. (Teachers might use professional examples like Gary Larson's *Far Side* as models.)

(5) Analyze the influence of media on people's understanding of science issues. Or, make generalizations about the prominence of certain science issues in the media at certain times.

(6) Analyze a governmental position on a particular issue that affects health, technology, or the environment. (Teachers should take into account factors like fiscal restraint, rights of various stakeholders, political considerations.) Or, debate the issue of the scientists' view opposed to the bureaucratic stance.

(7) Analyze and compare newspaper editorials about certain science issues, examining and evaluating authors' views, the accuracy of information presented, the simplification of information for lay audience, etc. (You may find essays by David Suzuki, Carl Sagan, Isaac

Asimov, Lewis Thomas, Rachel Carson, and other scientists who write well helpful.)

(8) Analyze a case study of a science-technology-society issue using science concepts learned. (Material for case studies may be borrowed from current events, such as decisions being debated at government levels regarding the Al-Pac mill or the Oldman Dam. Have students research the case in groups, obtaining the necessary information from the media, government reports, interviews, etc., then propose their group's recommended decision.)

(9) Create a storyboard for a film to show a process or explain a concept for a particular audience.

(10) Dramatize a scientific concept or process, and present the concept to elementary or junior high students.

(11) Analyze the treatment of a science-technology-society issue in a feature film, noting its presentation, accuracy, viewpoint presented. Or, analyze and evaluate an extrapolation of some piece of current scientific knowledge to predict conditions and developments in a science fiction film.

(12) Analyze the image of science and scientists on media (or, in advertisements, on television, etc.)

(13) Research and analyze the construction of special effects for feature films. Students might use helpful publications such as *Cinefex* (a periodical available quarterly from Valley Printers, P.O. Box 20027 Riverside California 92516)

(14) Analyze advertisements that use "scientific information" to support their claims. Evaluate the accuracy of the information presented, noting any important omissions and use of "weasel words." Or, analyze advertisements making claims about a particular product, then design experiments to test these.

(15) Debate the scientific use of animals for product testing.

(16) Evaluate and compare "environmentally friendly" products. Or, analyze advertisements for such products.

To evaluate students' ability to abstract, teachers might use DLCP instruments to help them measure the extent to which they: use symbol to represent abstractions, make plausible predictions based on abstractions, evaluate soundness of own generalizations, provide support for generalizations.

Monitoring

If students don't learn how to ***monitor*** their own science learning, they will likely not improve their learning skills. Teachers can use writing and discussion activities to help students affirm their understandings and locate their knowledge "gaps." Students can be encouraged to develop their own learning goals and make these explicit through writing. Students need to be helped to become aware of their problem-solving process by tracking and evaluating, in writing, the thinking process they use. Some other ways to involve students in monitoring their own learning include:

(1) Make use of learning logs which students write in at each class end. Periodically have students review, compare, and evaluate these logs.

(2) Have students assess the learning they demonstrate in their own tests, then have students write specific learning goals for themselves. Help them design learning strategies to achieve their goals.

(3) Have pairs or groups develop a genuine research question (something they really want to find the answers to) that extends a science unit or concept learned, then plan, conduct, and evaluate a project to answer the question. The research method might involve designing experiments, interviewing people, reviewing periodicals, or using other resources.

(4) Use spontaneous writing to help students track and compare the problem-solving process they use with the processes others use.

(5) After group work, have students themselves evaluate their individual and group progress towards mastery of one or two particular group skills that you have asked them to concentrate on. The following list of group skills may be used: asking questions, asking for clarification, checking for others' understanding, elaborating on each others' ideas, following directions, getting the group back to work, keeping track of time, listening actively, sharing information and ideas, staying on task, summarizing for understanding/paraphrasing.

(6) Record process of a complex experiment by taking color photos or slides, then arranging and presenting these as a photo-essay or documentary.

The ability of students to monitor can be evaluated by using DLCP instruments to measure the extent to which students set their own learning goals/purposes, plan learning strategies, persevere, or check own mistakes.

Writing Formats

There are a number of different writing formats. The list that follows is not exhaustive. It represents only a starting point to help students and teachers get their minds working. All of these forms can be adapted for use in a science class: adventure tale, advertisement, article, autobiography, biblical passage, billboard, biography, book review, brochure, case study, children's book, comic, cross word puzzle, editorial, epitaph, essay, fairy tale, greeting card, headlines, instructions, invitations, joke, journal/diary, letter, list, logbook, magazine, manual, menu, message, multiple-choice questions, myth, newspaper, pamphlet, photo-essay, poem, puns, quotations, rap (rhythmic chant popular in rock music), recipe, report, request, resume, review, riddle, schedule. script, slogan, song, story, story-board, summary, test, tongue twister, travelogue, want ads, worksheet.

Conclusion

The goal of the paper has been to help teachers by suggesting ways that they can incorporate the use of writing assignments in the senior high science program. Teachers can both help their students become better able to learn language and science concepts at the same time. But, attention must be paid to how language arts activities can be incorporated into science. Students will not simply absorb new concepts by listening to someone explain them. Instead, one of the best ways for students to improve science is for them to improve their language. To do this, students must internalize science concepts and skills by learning to use their own communication processes -- (1) reading, (2) writing, (3) speaking, (4) listening, and (5) viewing. Hopefully, this paper has presented a variety of activity ideas that will help teachers focus on using these five communication processes.

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