3 Writing and Problem Solving

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Problem solving is common ground for all the disciplines and fundamental to all human activities. A writer is a problem solver of a particular kind. Writers "solutions" will be determined by how they frame their problems, the goals they set for themselves, and the means or plans they adopt for achieving those goals.

The relationship between writing and problem solving has been most recently examined in the research of Linda S. Flower and John R. Hayes.[1] Flower and Hayes are among a number of researchers in diverse fields who have studied the cognitive processes of experts and novices thinking aloud on tape as they solved problems in mathematics, physics, chess playing, and composing.[2] The findings in all of these areas point to a common conclusion: whether the problem solver is a writer, a musician, a physicist, or a chess player, experts appear to have an arsenal of strategies which will direct them toward a seminal (if not final) solution. Novices, on the other hand, most often rely on trial and error. A novice chess player, for example, might randomly try a variety of moves in a chess problem; an expert, in contrast, will employ a powerful strategy, such as "try to control the center of the board," drawing from long term memory a pattern which matches the configuration on the board. Similarly, novice writers when given a composing task will simply begin writing while thinking aloud, hoping for the "right" sentence that will carry them through the whole written draft. Expert writers, like expert chess players, are able to draw strategies from long term memory which put them in "control of the board." These strategies involve setting and resetting goals, generating ideas, exploring their relationships, and finally connecting them in some kind of analytic framework aimed at a specific reader.

Although differing in theoretical assumptions and research methodology,[3] Flower and Hayes share with James Britton the view that writing involves highly complex cognitive processes. In heeding the research findings of those attempting to track these processes, we are

beginning to devise pedagogical techniques that help students tap their own tacit resources. This essay presents suggestions on how current research on problem solving can be put to use in writing as well as other content area courses. The first section demonstrates how a problem-solving approach can be used in a composition course; the ensuing section offers practical suggestions for using writing as a problem-solving tool in other disciplines.

A Problem-Solving Approach to Writing

Can strategies that experts use be taught to beginning writers? The question is not an easy one to answer because an expert will have both experience and procedural knowledge to draw upon as well as composing strategies. However, the research of Flower, Hayes, and Nancy Sommers (who has studied the revision strategies of expert and novice writers)[4] suggests that the techniques that experienced writers use can be modified for the classroom.

In fact a number of strategies have been adapted for both beginning and advanced writers based on the following assumptions: (1) Effective writing is a goal-directed, hierarchically organized, recursive process which requires an awareness of the relationship between subject, purpose, and audience. (2) A writer has literally dozens of constraints to juggle simultaneously, among them lexical and syntactic decisions, tone, diction, organization, not to mention the larger rhetorical problems. (3) Trying to write under the pressure of too many constraints frequently creates "writer's block." It is necessary to break the composing process down into a number of subprocesses which include setting goals, making plans, generating ideas, and organizing the ideas into some kind of structure easily accessible to a particular audience. (4) There are strategies that will help guide the writer through each of these subprocesses.

Goal Setting and Planning

Goal setting is one useful strategy for getting students started with what they often view as a dreaded task. The general goal has already been set by the teacher: "Write about x (subject) for y (audience)." A number of questions will help a student determine further goals:

> What do you hope to accomplish with what you write?
>
> Satisfy the teacher?
>
> Convince y that x is true?
>
> Impress y by showing how much you know about x?
>
> Something else?

Setting goals will encourage students to develop plans, that is, to think about the method or means by which they will reach their goal. Typically, as students begin to write, their goals change and break down into smaller units or subgoals. As their goal base changes, they will restructure and adapt plans to fit their deepening understanding of the task at hand.

Setting goals and refining plans to meet them should not be confused with outlining, which impedes these processes. Outlines are inflexible; goal setting and planning should be fluid and flexible, suited to the students' changing awareness of what they want to say and why.

Strategies for Idea Generating

The act of writing begets ideas which help refine goals and reshape plans. Generating ideas-getting one's thoughts into words-requires the loosening up of information a writer has tucked away in long-term memory. One strategy for the retrieval of ideas is making lists by simply jotting down ideas as they come without worrying about tying them together into neat little bundles of sentences and paragraphs. Another technique for mental retrieval is "brainstorming," that is, breaking the class into groups so that everyone can contribute as many ideas as they can. Usually, one person's thoughts will act as a catalyst and "spark" others in the group. The following exercise combines both these techniques.[5]

1. Imagine that you are a consultant for a brickyard which makes common red construction bricks and is in financial difficulties. The manager of the brickyard is interested in new uses for his products and has asked you to provide him with some. Spend ten minutes or so thinking about the problem and then write down on a sheet of paper as many new uses for bricks as you can think of.
   (Were you aware of what went on in your mind when you were thinking about the problem? You probably did some type of ad-hoc listing of alteratives. However, your conceptualization may have suffered from lack of focus or from a premature judgment that rejected ideas which seemed impractical, or from labeling, choosing only commonplace ideas.)
2. Now take a blank piece of paper and spend four minutes listing all the uses you can think of for bricks. Try to avoid premature judgment and labeling.
3. Make a list of the attributes of a brick (weight, color, porosity, etc.). In groups, based on your lists of attributes, make a common

> list of new uses for bricks. The rest of the class will then decide whether you are to receive a promotion or be fired.

Attribute listing is a strategy for developing greater fluency while getting ideas down. The brick exercise encourages students to think not only of what bricks as entities could be used for, but asks them additionally to break down their mental image of bricks. The listing of attributes should promote more (and wilder) ideas. In short, attribute listing helps overcome conceptual blocks that prevent the fullest expansion and flow of thoughts.

Another technique for releasing the flow of ideas is free writing. Free writing helps a writer turn off his or her mental "editor" (who is often preoccupied with the "good manners" of writing, such as spelling and grammar) and, as one writer who was trying to overcome a writing block put it, "free write your way to freedom." Furthermore, free writing allows one to hold considerations of form at bay and concentrate on getting down as many thoughts as possible. Two variations of free writing are, keeping a journal and "timed" or "shotgun" writings, which call for students to write down *everything* that is on their mind. During a "shotgun" exercise, the students are not to lift their pens from the paper; if they run out of things to say, they simply write "I have run out of things to say," until something pops into their head. Like listmaking, attribute listing, brainstorming, and journal writing, free writing helps students increase the output of ideas. After a sufficient quantity of ideas has been generated, they can go on to assess quality.

Developing Audience Awareness

Audience awareness, like goal setting, planning, and idea generating is recursive; that is, it is a matter of concern throughout the composing process. However, audience-directed strategies may be taught independently to help a class become aware of the fact that in "real world" writing there is a reader (other than the teacher) who should be taken very seriously. A clear sense of audience is just as important to the writing task as developing goals and plans, translating ideas into words, and organizing the material into some kind of logical structure.

A class should begin thinking about the identity of their reader even as an assignment is made. Questions similar to ones that Fred R. Pfister and Joanne F. Petrick asked their students will help fill out an image of the reader:

> What is his or her physical, social, and economic status? (age, environment, health, ethnic ties, class, income)
>
> What is his or her economic background?

> What are his or her ethical. concerns and values? (home, family, job success, religion, money, car, social acceptance)
> What are his or her beliefs and prejudices?[6]

Once students have a concrete picture of their reader in mind, they should next consider how they want to affect the reader's thinking about their subject, and, finally, by what means they can best achieve their purpose. For example: If they are trying to get their audience to change an opinion, what tone do they want to use? What diction? How much information do they need to present? How can they best organize that information? How long and complex should their sentences be? All of these choices will grow from an analysis of the audience that progresses from questions that give the reader a real world identity to questions of *how* a writer can best present a subject to this reader.

A teacher I know uses the following deceptively simple exercise in a technical writing course to get his students to think precisely about the relationship between audience, subject, and purpose:

> You are to write the instructions for making a house from Lincoln Logs for the ten-to-twelve-year-old readers of Jack and Jill magazine.

He then brings the Lincoln Logs to class and role-plays a child following each set of instructions to the letter. The log house exercise vividly demonstrates to students the importance of a clear sense of audience.

Visualizing the Idea Structure

Listing, brainstorming, and free writing are powerful strategies for getting ideas on paper, but students will need another kind of strategy to help them organize their thoughts so that a reader can grasp the relationships among their ideas. A tree diagram or flow chart of ideas drawn after the students have done a free write or journal write or first draft will give them a visual representation of how their ideas may best be arranged into a tight structure. Figure 1 shows an "idea tree" by which an engineering student diagrammed his ideas for the assignment, "What makes writing difficult?" In a first draft this student had brainstormed effectively-so effectively that his paper was a morass of unrelated ideas on the sources of writing difficulties: "fear of writing," "lack of motivation," "no plan of attack," "poor vocabulary," "purpose of paper not defined." Class discussion brought out the fact that he knew his paper lacked organization, yet he had no means for pulling his ideas together. I asked him to use the tree structure to visually rank the ideas in the paper, beginning with the most inclusive.

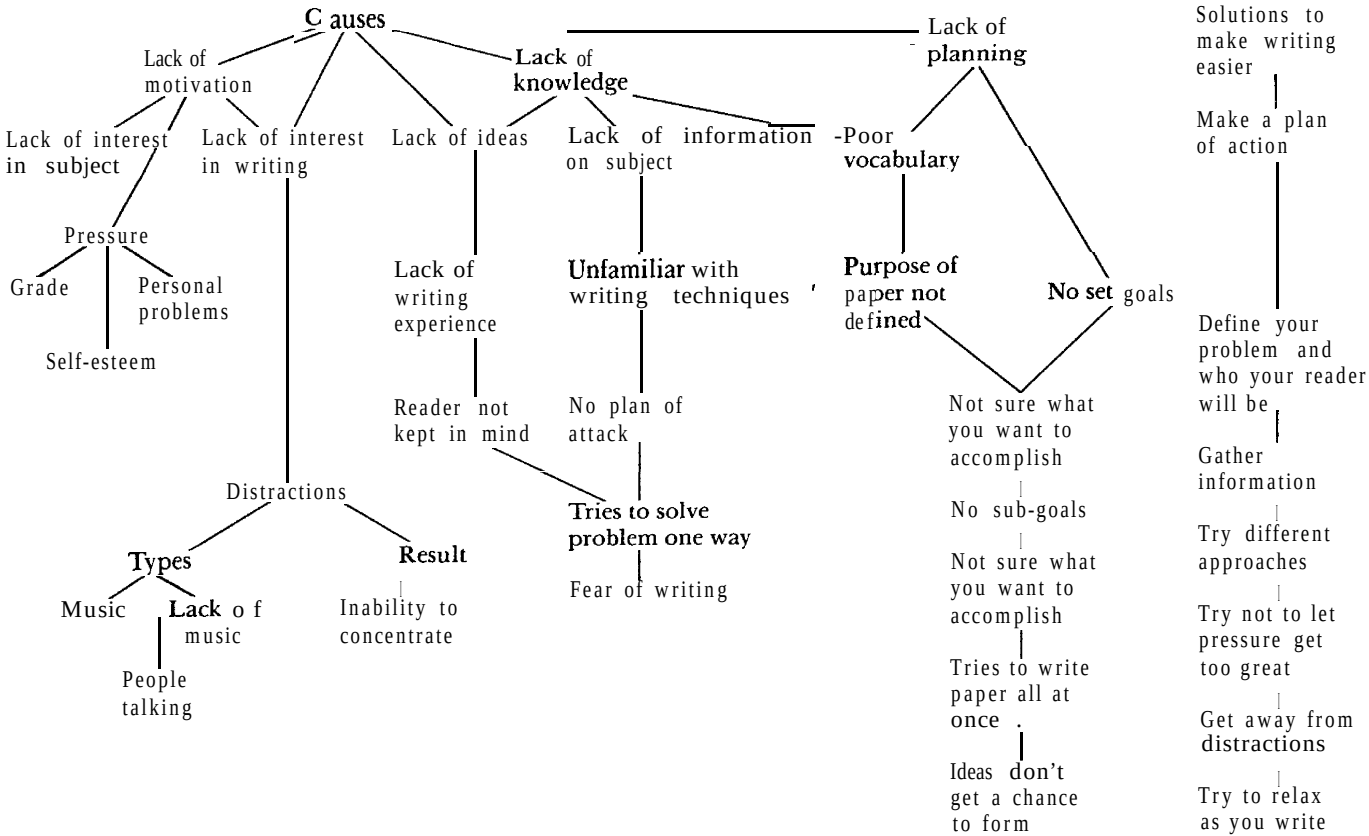

Figure 1. What makes writing difficult.

Writers can learn to use this strategy by analyzing someone else's writing first; for example, by diagramming the underlying idea structure in a long editorial in a newspaper or in an essay in a rhetoric reader. After students begin to feel comfortable with the technique ask them to use it on their own work. Chances are, they won't find as well developed an idea structure. If the ideas do not connect to each other or if the tree looks pretty bare, this means they need to do some rearranging and perhaps some more goal setting and idea generating.

Representing ideas graphically in an idea tree creates a hierarchical structure, that is, a structure which shows the relationship between superordinate and subordinate ideas. Students with some background in computer science find the flow chart a handy way to visualize idea relationships- though the flow chart, unlike the idea tree, is a closed system. The point is- whatever the technique-visualization facilitates the organization of ideas, which, in turn, helps to make them more easily accessible to a reader.

In summary, asking questions to set goals, making lists of ideas and attributes, brainstorming, free writing to get ideas flowing, developing a clear picture of the reader through the use of questions, and graphically representing the underlying idea structure of prose are all strategies to aid writers as they compose. These strategies are not rule-governed procedures that guarantee a solution. They do offer a high probability of success, or as Flower and Hayes point out, "formulize the efficient procedures a good journalist or scientist would use unconsciously."[7] The problem-solving approach to teaching writing gives a student a set of techniques useful in any course.

Writing and Problem Solving in Other Disciplines

The discovery function of writing in the content areas, particularly in the scientific and technological fields, can help students become aware of the processes they use to solve problems. Writing does this because, as James Britton has shown, "an essential part of the writing process is explaining the matter to oneself."[8] A colleague of mine, an engineer, asked his students to keep a journal, first to reflect on their preparatory reading before class, and then to summarize key concepts following the lecture. To his surprise, students produced flow charts, diagrams, and drawings integrated with their written responses. The students' journals illustrate a critical point: Because the professor was himself engaged in solving problems using what James L. Adams calls "alternate thinking languages"[9] (drawings, equations, slides), it was only natural that the students would respond in kind. The journal provided

them with a medium for switching back and forth between verbal and visual modes of thought.

However, students are not often encouraged to write for discovery purposes outside of their composition courses; nor are they taught to develop fluent and flexible thinking habits through the use of alternate languages as they work through problems. Consequently, faculty are confronted by students who claim they "hate writing" and who depend on the textbook to arrive at solutions to math, science, and engineering problems. One response to this curricular dilemma is to make the use of visual techniques such as tree diagrams and flow charts part of writing instruction across the curriculum. This will give students experience verbalizing the subject matter they are ordinarily taught to think about only in equations, formulas, or other nonverbal modes. The following writing strategies are intended for use in disciplines in which writing is usually not associated with course content.

Keeping a Strategy Notebook

Most problem solvers switch from one strategy to another in working toward a solution, sometimes without conscious awareness of what they are doing. A strategy notebook offers students an array of problem solving techniques from which to choose. James L. Adams, a teacher of design in the Engineering School of Stanford University, explains why this is desirable: "First by selecting strategies consciously one can often find approaches he would never have known about had he left the selection to his subconscious. Secondly, by becoming aware of various thinking strategies, what they can do, and how to use them, one can ensure that the mind has a larger selection when it utilizes its subconscious selection method."[10]

A strategy notebook might include a brief listing of conventional problem-solving methods such as induction, deduction, reduction/combination (breaking a problem down into subproblems) and analogy. *Strategy Notebook*, published by Interaction Associates, lists some sixty-six strategies accompanied by a description of each.[11] These strategies include:

Build up	Relax	Search	Transform
Eliminate	Dream	Select	Translate
Work Forward	Imagine	Plan	Expand
Work Backward	Purge	Predict	Reduce
Associate	Incubate	Assume	Exaggerate
Classify	Display	Question	Understate
Generalize	Organize	Hypothesize	Adapt
Exemplify	List	Guess	Substitute
Compare	Check	Define	Combine

Relate	Diagram	Symbolize	Separate
Commit	Chart	Stimulate	Change
Defer	Verbalize	Test	Vary
Leap In	Visualize	Play	Cycle
Hold Back	Memorize	Manipulate	Repeat
Focus	Recall	Copy	Systemize
Release	Record	Interpret	Randomize
Force	Retrieve		

Using the notebook as a source, an instructor might ask students to keep track of the strategies they are using at any time during a problem-solving activity. Students might also keep a strategy notebook inductively-to list strategies as they arise while the student goes through the step by step procedure of solving a problem. The notebook would, in either case, serve as a resource for strategies to use when a student is in trouble or seeking alternative approaches.

Focus on Conceptualization

Arthur Whimbey and Jack Lochhead have developed a technique that fosters verbal conceptualization by asking physics and math students to work in pairs on verbal reasoning problems. As one student works a problem, the other asks a series of questions aimed at getting the problem solver to verbalize the mental processes he or she is going through-a step at a time. The questioners are told to keep the problem solvers talking as they work in order to make them aware of what they are thinking at all times. Then the pair trades roles as they work another problem.

The following problem and solution is typical of the material Whimbey and Lochhead use with their students.

Problem

On a certain day I ate lunch at Tommy's, took out two books from the library *(The Sea Wolf* and *Martin Eden,* both by Jack London), visited the museum, and had a cavity filled, Tommy's is closed on Wednesday, the library is closed on weekends, the museum is only open Monday, Wednesday and Friday, and my dentist has office hours Tuesday, Friday and Saturday. On which day of the week did I do all these things?

Solving the Problem

Step 1. Suggestion for beginning the problem: The restrictions on when these activities occurred are stated in the second sentence.

Step 2. Tommy's is closed on Wednesday . . .

S M T ~~W~~ TH F SAT

Step 3. . . . the library is closed on weekends . . .

~~S~~ M T ~~W~~ TH F ~~SAT~~

Step 4. . . . the museum is only open Monday, Wednesday and Friday . . . This means it is closed the other days.

~~S~~ M ~~T~~ ~~W~~ ~~TH~~ F ~~SAT~~

Step 5. . . . and my dentist has office hours Tuesday, Friday and Saturday. This eliminates Monday.

~~S~~ ~~M~~ ~~T~~ ~~W~~ ~~TH~~ F ~~SAT~~

Step 6. On which day of the week did I do all these things: Friday.[12]

Using Polya's Check List

In addition to asking students to use writing/talking to keep track of how they solve problems, a notebook can be used to record responses to a check list of problem-solving procedures, such as those developed by the mathematician George Polya in *How to Solve It.* Polya frames a series of questions directed toward four goals: (1) understanding the problem, (2) finding the connection between the data and the unknown (which may involve considering auxiliary problems if an immediate connection cannot be found) in order to eventually obtain a plan of the solution, (3) carrying out the plan, (4) examining the solution obtained (checking back). The questions include:

Understanding the Problem

What is the unknown? What are the data? What is the condition?

Is it possible to satisfy the condition? Is the condition sufficient to determine the unknown? Or is it insufficient? Or redundant? Or contradictory?

Separate the various parts of the condition. Can you write them down?

Devising a Plan

Have you seen the same problem in a slightly different form?

Do you know a related problem?

Look at the unknown! And try to think of a familiar problem having the same or a similar unknown.

Could you restate the problem? Could you restate it still differently? Go back to definitions.

If you cannot solve the proposed problem try to solve first some related problem. Could you imagine a more accessible related problem? A more general problem? A more special problem? An analogous problem? Could you solve a part of the problem?

Did you use all the data? Did you use the whole condition? Have you taken into account all essential notions involved in the problem?

Carrying Out the Plan

Carrying out your plan of the solution *check each step.* Can you see clearly that the step is correct?

Looking Back

Can you check the result? Can you check the argument?

Can you see [the result] at a glance?

Can you use the result, or the method, for some other problem?[13]

Polya's questions themselves suggest strategies. They direct a student to break a problem down by setting a series of goals and subgoals, to use analogy, to develop plans, and to consider alternative solution procedures. Moreover, the questions invite responses that evoke verbal, visual, and mathematical notation. Like the strategy notebook and the Whimbey/Lochhead questioning technique, the check list is a discovery tool-it helps students to conceptualize their mental processes while they are actively engaged in solving problems.

The techniques of using writing interactively with visual and mathematical notation in a journal or notebook and of asking students to think aloud while solving problems have several heuristic functions: developing fluency and flexibility as students become adept at using alternate thinking languages; fostering and facilitating creative thinking; making students conscious of the step-by-step processes they use as they solve problems; developing the ability to conceptualize in a variety of content areas.

These last two functions may be particularly important if students are to transfer general problem-solving strategies from one discipline to another. (As of this writing there are no studies of heuristic transfer; it is an area worthy of investigation.)

Good writers (and other problem solvers) have a large repertory of strategies to draw on. As a teacher my concern is with the practical application of these strategies in the classroom. The material in this chapter has several implications for teachers in all disciplines. To summarize:

> Writing as a problem-sol ving activity aims to make students self-conscious about the way they conceptualize.
>
> Self-consciousness about the way one solves problems (in writing or in other disciplines) leads to more effective conceptualization and, finally, becomes a strategy for solving problems.
>
> Good problem-solving strategies cross disciplinary lines; in writing they become a means for producing effective prose; in other content areas writing can become one among many strategies for learning.

Notes

1. See "Problem-Solving Strategies and the Writing Process," College English 39 (December 1977): 451; "The Cognition of Discovery: Defining a Rhetorical Problem," *College Composition and Communication* 31 (February 1980): 21-32. From their research Flower and Hayes have developed a theory and model of writing as a cognitive process. See *A Process Model of Composition,* Technical Report No. 1, Document Design Project funded by the National

Institute for Education (Carnegie-Mellon University, 1979): 400-78-0043; "A Cognitive Process Theory of Writing," a paper presented at the Conference on College Composition and Communication, Washington, D.C., March 1980.

2. This method of research, protocol analysis, is a sequential record of a subject's behavior while actively engaged in performing a task. Typically, a protocol includes a transcript of a tape recording made by the subject who has been asked to verbalize his or her thinking process as well as all notes, drawings, and written material.

3. Flower and Hayes differ from Britton in the nature of their writing models: Britton's linear model represents a series of stages separated in time: conception/incubation/production. [See James Britton, Tony Burgess, Nancy Martin, Alex McLeod, and Harold Rosen, *The Development of Writing Abilities (11-18)* (London: Macmillan Education, 1975).] In contrast, the Flower/Hayes model is recursive- at any time in the writing process, any or all elements of that process may be brought into play. For example, when writers are reviewing they may find that they are setting new goals and plans. In this sense the process is cyclical rather than linear.

4. See "Revision Strategies of Student Writers and Experienced Adult Writers," *College Composition and Communication 31* (May 1980): 378-388.

5. James L. Adams has developed this modification of 'J. P. Guilford's "brick use" test in *Conceptual Blockbusting* (New York: W. W. Norton, 1978), p. 79, a book that identifies various conceptual blocks and proposes strategies for overcoming them.

6. "A Heuristic Model for Creating a Writer's Audience," *College Composition and Communication 31* (May 1980): 214.

7. "Problem-Solving Strategies and the Writing Process," *College English* 39 (December 1977): 451.

8. Britton, p. 28.

9. Adams, pp. 93-l 11.

10. Adams, p. 68.

11. Adams, p. 66.

12. *Problem-Solving and Comprehension: A Short Course in Analytic Reasoning* (Philadelphia: The Franklin Institute Press, 1979), pp. 57-60.

13. Adams, pp. 89-90; adapted from George Polya, *How to Solve It: A New Aspect of Mathematical Method* (Princeton, N. J.: Princeton University Press, 1945), pp. 6-15.