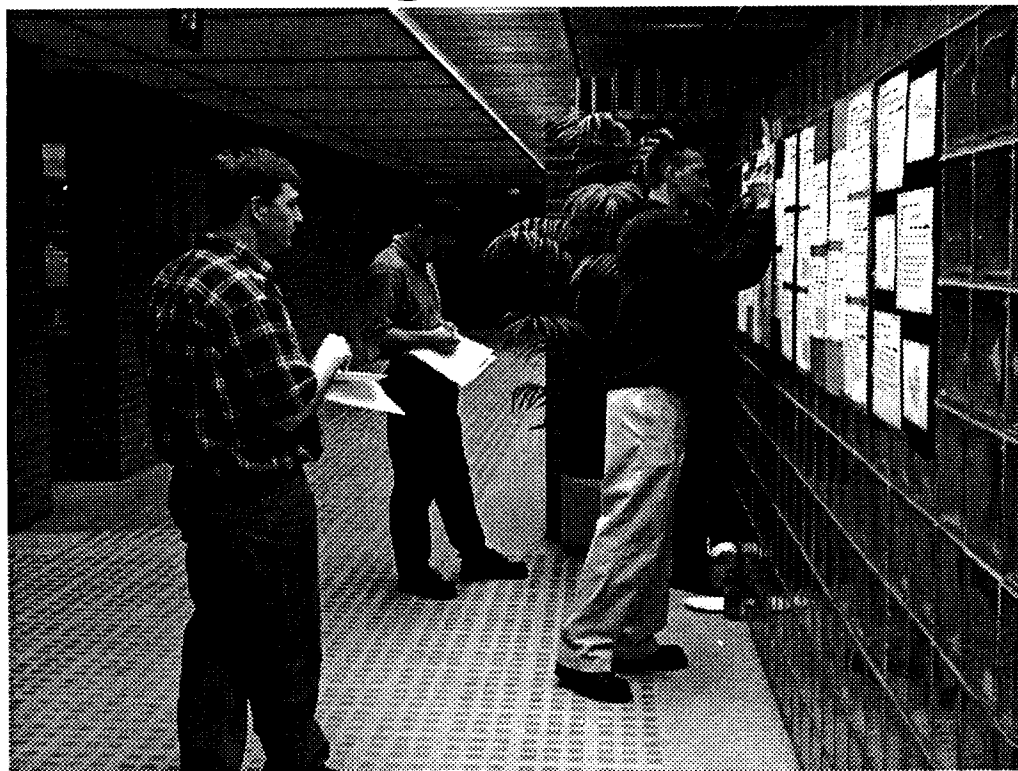# Physical Chemistry Laboratory Projects:

An Integrated Approach to Student Learning

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"Fluorescence Studies of the Acidity Constant of 2-Naphthol," "IR Absorption by Atmospheric CO_2," "Computational Studies of a Series of Conjugated Dyes."

These topics, chosen by students last year for their Physical Chemistry Laboratory final project, culminated a two semester course in physical chemistry with both lecture and laboratory components. Their final project was designed to provide students with the opportunity to:

•become more independent in the laboratory (certainly an important skill in their future careers as scientists)
•present scientific results in a typical conference setting
•learn from the work of their peers
•recognize the relevance of physical chemistry to all branches of chemistry.

Physical Chemistry is often perceived as the most difficult part of the undergraduate curriculum. It is certainly the most theoretical, requiring an integration of chemical, physical and mathematical concepts. The Physical Chemistry Laboratory, a two-semester sequence which complements the Physical Chemistry Lecture, is intended to make the seemingly abstract concepts of physical chemistry more concrete. This goal is first accomplished through a series of laboratory "experiments" which allow the students to gain experience with scientific measurement and data reduction. The students are required to complete the experiments, analyze the data and present their results in written laboratory reports.

During the course of the two semesters, the students write seven "formal" reports, in the style of a paper publishable in the journals of the American Chemical Society. They also write approximately three summary reports, which are intended to model appropriate data reporting to a supervisor in industry. The two pedagogical goals for these reports are to reinforce scientific concepts through writing, and to teach students how to communicate scientific information using the format and language conventions of the community of professional chemists.

Since students taking Physical Chemistry are junior and senior chemistry majors, they are ready for additional challenge in the laboratory setting. Last year, I added the independent laboratory project and have since made it a permanent part of the program. Working in pairs, students develop and implement a short experiment on their own, with much less direction than they have typically encountered in the past. They begin by choosing a topic, usually from a stack of papers that I have collected, but they are free to choose any project, as long as it relates to physical chemistry and the equipment and supplies are readily available (and not prohibitively expensive). They are responsible for determining what supplies they need, establishing a method, executing the experiment, analyzing the data and presenting the work to their peers and the faculty of SE&T. The presentations take the form of a scientific poster session, similar in format to a poster session at any major scientific meeting. The project occurs in the latter half of the semester, but planning begins early, as shown in the time line below.

Time Line

Week	Task
1	Students are introduced to the special project
4	Students choose partners and topic and discuss their topics with me

5	Students turn in "proposal" consisting of:
	    Title
	    Goal of Experiment
	    Primary Reference
	    List of needed chemicals, supplies and equipment
	    Laboratory procedure

8	Begin Laboratory Work
12	Poster Session

I chose the poster format instead of formal written papers or oral presentations for several rea-

Guidelines for Poster Presentation

1. A poster should be self explanatory. Although the presenter will stand by the poster most of the time, the poster should be complete enough that a viewer could get the gist of the work and most of the details just by reading and looking at the figures.

2. All of the pertinent information that would usually be in a lab report or paper should be presented in your poster. However, since a person needs to read it from a distance, bullet lists and tables should be used instead of detailed prose.
Specifically, the poster should include:

    a) **Introduction**
        Include goal of project, significance, and pertinent background information
    b) **Theory**
        Describe how the experiment works
    c) **Materials and methods**
        Be sure to include all relevant experimental conditions, such as actual
        concentrations, temperature (if appropriate), pH (if appropriate)
    d) **Results**
        Use tables, graphs, raw data (if appropriate)
        Describe any calculations (you don't need to show details, unless that is the
        point of the poster!)
    e) **Error analysis**
        You don't need to show details of error analysis, but you must estimate errors in
        your experiments. You should indicate how errors were derived (e.g. standard
        deviations or propagation of errors through calculations)
    f) **Conclusion**
        What did you learn?
    g) **References**
        Cite the primary article that you used and any other sources
        Use ACS format

The text and graphs should be readable from 4 feet. You may use either word processing software or presentation software, but make sure your poster is neat and legible.

Attractiveness is an important feature in posters because a well-done poster will draw more people and more discussion. This is GOOD-even if it makes you nervous at first. Use of colors can make a poster very attractive and effective, and I will be happy to print out color pages for you if you bring your work to me on disk at least one day early.

sons. I wanted the students to learn from each others' work, which is difficult with written papers. I didn't want the students to report their results to me, but to each other. I didn't want them to be able to gloss over muddy points which is easy to do in a written report but much harder in a discussion format where questions are being asked. This forces them to think carefully and thoroughly about their topics. Formal oral presentations accomplish these objectives, but are stressful, time consuming and the audience frequently becomes passive.

The Physical Chemistry Laboratory, a two-semester sequence which complements the Physical Chemistry Lecture, is intended to make the seemingly abstract concepts of physical chemistry more concrete.

In poster sessions, both audience and presenters are active participants and learn from the experience. Since the poster presentation is less formal than an oral presentation, it is easier for the presenter to accept input and suggestions open-mindedly. Finally, posters are a very common format at national scientific meetings where the vast number of contributed papers precludes including all presenters in oral sessions. This format has been used effectively by other departments at SVSU for similar assignments.

The construction of an effective poster requires the students to communicate effectively in a somewhat prescribed format The poster must contain as much information as a written paper or an oral presentation, but must present that information in a more limited space. Graphics and text must be used effectively to clearly emphasize the major points of the work, and supporting evidence must be presented to justify all conclusions.

Posters are viewed from a distance, which means that all text and graphs must be in large fonts and bold colors. Bullet lists are usually most effective; there simply isn't room for verbosity. The author is usually present at the poster, but the poster should be self explanatory, so that the viewer can easily ascertain the major points just from reading. The specific guidelines that I give the students are reproduced in the text box on page two.

This project demands much of both student and instructor. The students are asked to integrate many higher order learning and thinking skills in a project that involves laboratory work, library research, mathematical data analysis and written and oral communication. The project requires me to step out of the familiar as well. Instead of supervising the students on laboratory exercises that I know in detail--indeed, exercises carefully chosen because they work well--I learn with the

students as they explore specific applications of physical chemistry that are perhaps new to all of us.

The atmosphere in the laboratory changes dramatically as students engage in these projects. First, they must learn to grapple with the problems and overcome difficulties, since the details of their projects may be unfamiliar to me. The students must take responsibility for their work in significant ways. No longer can they blame equipment, instructors or instructions if they have problems. They developed their procedure so if it doesn't work, it is their job to "fix" it. The first year that we did this, I was surprised that students asked to come in for extra laboratory hours so that they could try a new approach, improve their results or simply try again. Their attitudes changed; instead of the laboratory being an exercise to complete as quickly as possible, it becomes a challenge and much more important to them. In short, they cared. Some students cared so much that I heard victory cheers when their experiments worked and saw a few tears of frustration when they didn't.

The poster session was held in the evening, with all laboratory sections displaying their work at the same time. Refreshments were served to create a relaxed atmosphere. The students were required to spend half the time at their own poster and the other half of the time learning about the other projects. Since they worked in pairs, there was always someone present at each poster. Each student was required to write a short summary of each poster. Students were offered "extra credit" for a detailed summary of any project (not their own). These latter tactics insured that the students would be an attentive and interested audience and engage in meaningful scientific discussions.

By all measures, the poster presentations were a resounding success. The students were proud of their work and did an excellent job of discussing their results with each other and with the faculty. The posters were very professional and looked as if they had come from an actual scientific meeting. I left the posters on display for a few weeks after the presentations and witnessed some students discussing their projects long after the assignment was completed and graded. Although I did not ask for formal feedback, students commented that they learned a great deal from the experience and hoped that it would continue in future years.

The real value in this project was that students were asked to integrate seemingly disparate knowledge into one project. They needed to apply their knowledge of fundamental chemical principles, their acquired laboratory skills, their ability to read critically, their knowledge of mathematical and graphical data analysis and their written and oral communication skills to their chosen topic in physical chemistry. I report, with a great deal of satisfaction, that the students were challenged by this assignment, but met that challenge and significantly exceeded my expectations.

It is no exaggeration to say that most incoming freshman students must undergo a significant transformation if they are to become successful writers in the academic community. There are several reasons for this. A major reason is the type of writing instruction many have received in their previous education.

Early in the fall semester, Writing Center mentors hosted all 42 sections of English 111 (Composition I). With English 111 now a single required prerequisite to the General Education Curriculum, we wanted all freshman students to know that feedback and assistance were available to them as developing writers. We also wanted them to hear the strategies that successful upperclass students use when writing.

As an opening activity during those visits, we asked students to respond to this question: What is the best or worst writing advice you have ever received? As we collected and analyzed their responses, patterns emerged.

Virtually no one recalled any advice that linked writing to engagement with a topic, or to understanding the complexity of a controversial issue. Most demonstrated a Rule-Based Writing (RBW) view: writing as "finding 'The Way' to learn 'The Answer,'" writing as "following the Rules": "Your paper should have an introduction, conclusion, and three body paragraphs"; "A good paragraph has seven sentences"; "Start your introduction with a question"; "Always restate your thesis in the conclusion"; "Write simple sentences so you won't make any mistakes." In other words, most freshmen enter with a notion that writing is either right or wrong, that RBW is the necessary strategy for success as a writer.

Given this background, the transition to University assignments, which require students to grapple with unfamiliar processes and formats, stretch their thinking when writing, and recognize that purpose and audience and context shape the decisions a writer must make, may seem like the equivalent of learning a new foreign language.

Consequently, many students are in a state of disequilibrium when first confronted with open-ended essay questions, or formal assignments that require a complex series of thinking processes, or types of writing they have never attempted. Typically, their first instinct when entering this unfamiliar territory will be to revert to "the Rules," the formulas about writing they have heard, whether or not these are useful or appropriate for the current writing task.

Unfortunately, this RBW view is often reinforced by teachers in the very language of writing assignments. When instructions are all about format and margins and whether or nor contractions are appropriate, rather than about ways of thinking or processes for writing various types of papers, students will deduce that what teachers care about most is RBW. And if instructor feedback focuses only on correctness (as essential as that is for clarity), students may conscientiously run Spell-check, but be completely oblivious to glaring contradictions within a paper.

Previous writing instruction, however, is only one aspect of RBW. An equally significant factor is the "low level cognitive complexity" which characterizes most entering college students, the dualistic thinking which Craig Nelson from Indiana University, in his work on critical thinking, calls the Sgt. Friday ("just the facts, ma'am")

Beyond Rule-Based Writing

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Instructional Support Programs

mode of thinking and writing. Things are either right or wrong; learning means accumulating facts and then regurgitating them; memorize, don't analyze. Students in a study by Joyce Magotto represented writing as "a rule-bound, monolithic system of right and wrong," and were "clear and candid about their personal purpose for writing college papers--to persuade an instructor to give them a good grade" (as cited in Bell, 2001, p. 89).

Thus for those of us teaching in the General Education curriculum (and perhaps beyond), there is likely to be a large gap between what we see initially in student writing and the goals we have set for student learning. When we encounter the RBW mindset, both we and the students may be frustrated.

Recent research on cognitive development provides some help. Fischer and Biddell's 1998 research identified "Characteristics of High Support Environments" in which students are likely to make the most significant intellectual growth; their research found that students learn best when the "entire [course] procedure [is] designed to support high-level performance and minimize interference with it." In such an environment,
_Tasks are straightforward and well defined
_Procedures are familiar to participants
_There is no emotional interference.
Most important,
_The context should prime high-level functioning; social priming by a more knowledgeable person is

"Per cent" is two words.

"Access" is not a verb; "Impact," unlike "access" is a verb, but it has not the sense people are carelessly assigning to it.

"Behaviors" can no more be found in a dictionary than "deers" or "mooses" can, and for the same reasons.

This small collection of writing-related bits of wisdom and many more were installed in my brain by way of off-topic, pointed anecdotes delivered by my very first Philosophy professor, David Rayfield. I describe these comments as off-topic because one would not expect that courses such as Law, Liberty, and Morality or Philosophy of Art would feature such discussions. But with Professor Rayfield as the instructor, these asides and many others are common.

That is not to say that these temporary scenic routes in a lecture on Plato's "Parable of the Cave" are not welcome; on the contrary. Professor Rayfield's combination of dry humor and mild irritation over the misuse of the English language creates an overall positive learning experience which is nothing short of memorable.

The Philosophy of Writing

K.L. Manwell

"Per cent" is two words. "Access" is not a verb; "Impact," unlike "access" is a verb, but it has not the sense people are carelessly assigning to it. "Behaviors" can no more be found in a dictionary than "deers" or "mooses" can, and for the same reasons.

Through the vocalization of his most peevish pet-peeves, Professor Rayfield makes his students consider the meaning--or whether there is one at all--behind the things they say and write. His constant critique of slang and other revisions to the English language not only makes his students think before they speak, but more important, begin to think before they write. After all, we would be graded not on the things that we said but rather the things that we wrote. And he made sure that we paid attention to our writing; with a 20% deduction for the misuse of grammar and an additional 20% deduction for an unclear argument, we, as students, had a very real interest in examining our writing before he did.

Which was why, when he announced to his Symbolic Logic class (my sixth course with him), "Today is my birthday and I have just been informed by my doctor that I have arthritis. So it appears that I will suffer from occasional, constant pain," I had two distinct thoughts. First, arthritis was a sub-par birthday present. Second, the word combination "occasional-constant" sounded like an oxymoron. "Occasional" meant "impermanent" or "fleeting," but "constant" meant the opposite: permanent, unchanging. Of course, it was not safe to trust my own intuition, so I looked both terms up in Webster's Dictionary.

Unfortunately, the phrase was not an oxymoron after all; I had not caught my instructor in a moment of error. Alas, I discovered that "constant" can mean either "that which is permanent or invariable" or "continually recurring." The latter definition seemed to eliminate the contradiction. However, I looked for "occasional" just to be thorough. Unfortunately, I could not find it at all. I shall, so to speak, give it the benefit of the doubt and assume that it is in the Oxford English Dictionary, which is--according to the illustrious professor--superior by far to Webster's.

My point is that this invaluable process of critically questioning the phrases writers create with the English language is consistently encouraged by the "occasional, constant" rants of Professor Rayfield. Although his technique is verbal, once I started thinking critically, it was a short step from there to applying this to my writing. Rather than simply recording my ideas on paper (without regard for the strength of the claims), I found myself able to utilize a tool which enabled me to build a justification for those claims simply by being critical of them.

Although my first experience with constructive criticism was in one of Rayfield's courses, it was reinforced in every other philosophy class I attended and encouraged by professors Hill, Hinderer, and Koperski. All of these people seemed in league with one another, determined to ferret out the good writer that was buried deep inside of me. As their spoken and written comments forced me to expand, develop, and clarify my thoughts as I both spoke and wrote, I built on the techniques Rayfield had instilled in me. His oral critiques created an implied standard which all of us had to rise to meet with our writing.

As I look back over the six semesters that I have taken classes with Philosophy instructors, I realize something that I didn't see at the time. I realize that those first, uncomfortable, intimidating instances where criticism--scathing to the inexperienced writer--was applied to my writing marked the beginning of something truly significant. Instead of being reinforced for simply writing coherently, as I had been in the past, I was being asked to evaluate my writing in terms of it being good writing.

In this process of examining my words critically, I learned to locate incomplete explanations and incorrect references. Once I was able to do this, I found that my writing could only benefit when I forced myself out of the author's position and into a more objective point of view. This critical self-examination has enabled me to identify my writing weaknesses, my first step in ultimately being able to organize a paper so that it became a logical, thoughtful, accurate presentation of my ideas.

In short, Rayfield's method of improving our writing began with examining interesting inconsistencies in the English language, both spoken and

I was sitting in Doan Cafeteria late one winter afternoon. The booths on either side of me were occupied by two groups of black students, similarly dressed in their winter coats and knit caps. I was engrossed in pizza and a newspaper, in a few minutes of downtime before my evening class. My primary concern wasn't people-watching. But I soon realized from overhearing little bits of conversation that only one group was from Michigan and spoke like city kids from Saginaw, Flint or Detroit. The other group was speaking French, from Franco phonic nations in Africa or the Caribbean.

A few nights later I was in Zahnow Library. I wandered from the Art section on the third floor, curious as to what other areas I'd find. I was surprised to come upon a young man in one secluded corridor kneeling towards the east, saying his prayers appropriate to that time of day, facing Mecca.

Not From Around Here: Foreign Students and Mid-Michigan Language

Michael R. Mosher
SVSU Art Department

Even out here in the beet fields we are participating in a global environment, pushed forth and facilitated by business and political globalism. Whether you embrace it fully or would rather be on the barricades in Seattle, Montreal and Genoa, it's here. While I grew up in Michigan, I had some misgivings about moving back here in 2000 from multi-cultural Silicon Valley, California. At Saginaw Valley I am especially pleased to find our foreign students providing a challenge to that, broadening and enlivening the campus cultural atmosphere for us all.

A university classroom is, by its nature, a pretty complex place, at best aflight with multiple ideas and meanings . As intellectuals, faculty are constantly adding shading and nuance to their messages, quick to point out "on the other hand", and this baffles (while broadening) all students. Added to this complexity foreign students may bring somewhat different behaviors. Very soon we learn to differentiate in them the yes of "I'm here" versus the yes of agreement and understanding. Sometimes they need convincing that to be seen taking notes (or following along on the computer with each step of tonight's software demo) indicates seriousness to an American professor.

I believe that foreign students make me a better professor. I find I pay more attention to enunciating clearly, talking in measured tones and not too quickly, further emphasizing important points or terminology, reiterating concepts using different terms. In my experience foreign students, much like mid-Michigan ones at SVSU, tend to prefer structure and metrics for each lesson and assignment, less so ambiguity and improvisation. None

of these improvements in delivery or greater organization of content are wasted on other students, who appreciate additional clarity. In many ways an eighteen-year-old from a small rural town has as much difficulty in comprehension of college material as someone for whom English is a second language.

We Americans are so used to our particular sea of glib journalism and its clichés that it takes a foreign student's inquiry to make us clearly see it. After assigning a Web search on prominent figures in the construction of the Internet, one woman from Asia e-mailed me that she was baffled at the word "guru" repeatedly applied by journalists to Vinton Cerf, a computer scientist instrumental in developing the protocol by which computers communicate over phone lines. The dictionary definition offered little popular context.

Despite this kind of active inquiry, it remains of concern to many of us that our foreign students are mastering our language. I propose we give them a friendly push into the deep end of the pool of local cultures, to immerse them in mid-Michigan ways and subtleties.

Attending Bay City's "River of Time" historical pageant this September, I was stopped by an enthusiastic official of the local Historical Association. She expressed how delightful and rewarding it was to work with one of SVSU's Communication Multimedia graduate students in the development of a multimedia CD-ROM and kiosk about local history. Echoing the French traveler De Tocqueville 170 years before, the grad student had expressed to her his surprise at how much energy Americans devoted to voluntary associations, in time-consuming projects like that weekend's Civil War re-enactments. The Historical Association officer said she'd never paid attention to news of Taiwan before, but did now that she had a friend from there with whom she worked. A student from another land benefits from direct contact, in a nuts-and-bolts project, with local citizens, while the experience gently broadened their international awareness in turn.

Specific projects are certainly the best means for greater integration between foreign students and the local communities around us. But even without the framework of projects, these students need to be parachuted into unfamiliar social environs. I would like to see our foreign students taken in by area service clubs, churches, synagogues, Toastmasters, unions, veterans' organizations, helping at charities and stuffing envelopes for Democrats and Republicans. Let's just put the names of the organizations in a hat, have the students draw them at random and commit one night a week to participation there. Let's volunteer them as teachers' aides in local public and private schools, perhaps guided by a student teacher.

Challenging? You bet. Our students must become familiar with Michigan or Midwest style and informal adult discourse, the friendly and chatty women in banks and offices, the way men kid each other. I want to know they're hanging out with talkative and opinionated Americans,

hearing Americans' stories told at the usual pace and peppered with the usual slang, euphemisms and cuss words.

Why is this important? Someday soon our students will find themselves working for a company in their home country. One day the boss will put down the phone and excitedly announce "Good news! We have the chance to bid on a big contract in Detroit (or Chicago, or Indianapolis, or Houston or San José). We're sending YOU to make the deal because you studied in Michigan." I want that student comfortable and fluent in midwest business style, the proper banter on the golf course and Board meeting. When they get off the plane at Chicago's O'Hare they'll tell their hosts "Whew, quite a season for the Bulls, eh?" Seriously, we must see a part of our purpose at SVSU as turning students from overseas into tri-city Rotarians.

Please join me in applauding the courage of our foreign students, journeying to mid-Michigan far away from their own communities. These ambitious people now at SVSU are adventurers, coming to study in the middle of the United States where there are rarely people from their homeland to be found nearby off campus. I expect someday to open Fortune magazine and see that southeast Asian woman appointed as Minister of Telecommunications for her nation, or read in Computer Graphics World how that quiet young man now directs a computer animation studio in Taipei. And that's because while they return to professional lives as productive and patriotic citizens of their own lands, there will always be a part of them that's distinctly University Center, Michigan.

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written. While he criticized the use of "access" as a verb, he also criticized words and phases in philosophical texts for their lack of clarity. It was, in effect, a double whammy. We were attacked by criticism of writing and we were attacked by criticism of spoken language.

Out of the instinctual, self-preservation motive, we learned to be critical of our own words.

We learned to question our thoughts before we wrote them down. We learned to critique the words that we used to articulate our opinions. Though all of this was necessary to avoid the wrath of the infamous grading pen, simple fear was not the lone motivation to improve our writing. Once our critical thinking skills had been awakened by other similar presentations, how could we ignore the challenges (such as the awkward sound of "occasional constant")? How could we not investigate?

Although this technique of painstaking critique may not be effective for everyone, I owe a great deal to Professor Rayfield for introducing me to this invaluable tool: the ability to ask myself, "Is this good writing?" And now that life leads me away from the thought-provoking, benevolent critiques of my professors, I shall always remember and utilize this hard-earned gift; I thank them for instructing me in what I can only describe as the Philosophy of Writing.

> As I look back over the six semesters that I have taken classes with Philosophy instructors, I realize something that I didn't see at the time. I realize that those first, uncomfortable, intimidating instances where criticism--scathing to the inexperienced writer--was applied to my writing marked the beginning of something truly significant.

often especially effective. Successful priming procedures include

    a) demonstrating a task and asking people to imitate it
    b) explaining the gist of a task
    c) providing a prototype of an effective solution to a task.
    (as cited in Lynch, 2001)

Some developmental psychologists have applied their research directly to the classroom. One particularly useful tool by Cindy Lynch lays out Steps for Better Thinking and the characteristics of students at each step, from the foundational to the highest cognitive complexity:

Lynch's model also includes prompts for questions or writing which correspond to each step, prompts which I have found very useful and would be happy to give to anyone who is interested.

Student transformation can and does occur every day. With "priming procedures" such as carefully constructed and sequenced assignments based on course outcomes; appropriate encouragement and modeling; clearly explained processes and strategies for various types of writing; and feedback that helps students grow in their thinking, as well as in their writing, students do develop the capacity to take on complex issues and

write about them cogently and meaningfully. Perhaps most importantly, such teaching strategies help students care about their writing, and students who care are more likely to apply "the Rules" for a higher purpose: to establish credibility and communicate clearly with their reader.

If we recognize RBW as an early stage of cognitive processing--and see our collective role as moving students to a higher level of thinking-- now our task becomes a most interesting challenge: how can we use writing to move each student toward higher levels of cognitive development?

Level	Developmental Characteristics
Foundational Knowledge and Skills (lowest cognitive complexity tasks)	Repeat or paraphrase information Perform tasks that can be evaluated as correct/incorrect
Step 1: Identify Problem, Relevant Information, and Uncertainties (low cognitive complexity tasks)	Identify reasons for uncertainty Identify alternative solutions and relevant information "Stack up" relevant reasons and evidence to support some solution or conclusion
Step 2: Analyze/Explore Connections (moderate cognitive complexity tasks)	Recognize and control for own biases Articulate assumptions and reasoning of alternative viewpoints Qualitatively interpret evidence Organize information meaningfully
Step 3: Evaluate Alternatives and Communicate Conclusions (high cognitive complexity tasks)	After thorough analysis, develop and use reasonable guidelines for prioritizing among factors and choosing among solution options Communicate appropriately for a given audience and setting
Step 4: Re-Address the Problem from a Life-Long Learning Perspective (highest cognitive complexity tasks)	Acknowledge and explain limitations of endorsed solution Integrate skills in ongoing process for generating and using information to monitor strategies and make reasonable modifications

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