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ABSTRACT

A study examined the effectiveness of incorporating writing as a tool to master the concepts of physics. Subjects were students in the three traditional physics classes and one non-math or conceptual physics class at East High School in Rockford, Illinois. The instructor tried a variety of methods--students wrote criticisms of Carl Sagan videos, wrote their own examples of a "system" after a lecture on the First Law of Thermodynamics, wrote their own test questions, drew pictures illustrating physical concepts, and wrote about personal experiences with physical concepts. Students looked forward to the writing assignments and their learning was far more auditory, synthesizing, and analyzing than the instructor ever realized. Most students did not like objective tests, and many preferred to take essay tests home and work on them for several days. Almost all students liked the group tests and the make-up-your-own tests. Findings suggest that using writing activities in the physics classroom can make physics less mystifying, less frightening, and more accessible to every student. (Contains 21 references. Appendixes present a list of several writing prompts, 13 lesson activities, and instructions for a laboratory activity involving hand-made ice cream.) (RS)

# WRITING FOR PHYSICS MASTERY

By

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# CHAPTER I

## Why Use Writing in a Physics Class?

### The Focus of the Study

Through the use of student writing, I developed alternative methods of evaluating student performance in physics. I wanted to rely less on the use of the traditional physics word problems, the questions at the end of the chapters and the objective tests developed by the book publishers. Only a handful of students ever really need the mathematical rigor of the traditional physics class. There was no reason to use applied mathematical rigor as the mainstay of student evaluation of physics principles.

The current technology that resides in every facet of life at home and at work requires more physics background than ever before. We have to make physics more accessible, less fearsome and give every student a sporting chance to excel in this subject area. Most students are more comfortable writing than figuring in their school work. More writing methods have to be explored to make physics comfortable to all students.

The Rationale for the Focus

The sciences of physics and chemistry have horribly neglected the use of writing by secondary students as a learning tool for mastery of ideas, skills and concepts. From my own past experiences as an engineer and with my secondary students in physics classes, the students have minimal ability to transfer knowledge from math class, English class or any in-school or out-of-school experiences to an applied science like physics. So much emphasis has traditionally been placed on the math formulas and the story problems of physics and chemistry. Students are left with few opportunities to think through or apply the ideas and concepts they are hearing in class, reading in their books or measuring in their lab activities to any other experiences. Experience in a professional laboratory or occupational environment would be preferable, but moneys for those opportunities will not be available soon, if ever. For example, one day recently several of my junior and senior physics students were amazed to discover that the light from the moon is reflected from the sun. They thought the moon made its own light. They said they had never thought about how the moon made its own light before. Thinking, through the process of writing, seems to be the only tool to practically and economically bridge this chasm from concept to reality.

Sadly, many students were not even reading their science books. They were relying on their memories and their haphazard class notes to "pass the tests." A student could say they didn't get the problem, shrug their shoulders and not try. They could say the examples in their books didn't make sense. But it was much harder for someone not to have an opinion on material they had to read. They could write about what they learned, what confused them, what mystified them or what parts they couldn't understand. The writing placed more responsibility on students than solving the math problems. It boggled my mind how much detail students could dredge up on a topic that they "didn't understand." They had to write their own questions about the material they were confused about. They had to feed back in writing what their difficulties were in short paragraphs to their instructor.

I taught physics and math for nine years after college. My enthusiasm waned and I changed jobs. I moved to industry where I taught heating, ventilating and air conditioning classes to adults for several years. In a series of further promotions, I became an application engineer, an electronics manufacturing engineer and an electronics design engineer for a group of air conditioning control products for large buildings. In my 13 years as an engineer in industry, I found that about 80% of my time was spent reading or writing rather than engineering on a draft board or a calculator. The kinds of written documents that I read, wrote, edited and evaluated were product and catalog literature, work instructions, product assembly instructions, lab procedures, test procedures, product and vendor specifications, building and bidding specifications, test reports, product failure analyses, customer letters, approval agency letters, technical training materials, meeting agendas, meeting minutes, and all manner of memos to associates and supervisors. I and my draftspeople would spend hours poring over every word and number on every blueprint for clarity as well as accuracy. My lab technician's laboratory test reports were hideously written until I sent the tech back to technical writing class. As a project engineer I was responsible for every single word and number that was written about my projects and my products on paper and on the blueprints.

After a downsize in my department, I decided to re-enter secondary education. Many retirements in the Rockford (IL) School District opened a position that was all physics teaching. I substitute taught for several months to see if I could still cut it in a classroom. I was suprised to find the kids were better than when I left 13 years before. I don't suppose that I became older and wiser than before, do you? I enjoyed the kids that I subbed with and was anxious to get back in the saddle, get chalk in my hands, and learn to appreciate bad lounge coffee again. I don't know what my attitude was but I wasn't the same person that left teaching thirteen years ago. I'm probably a lot better and I know that I project my confidence well. I probably acquired it from years of responsibility to my people and to my engineered products. I don't expend much energy controlling class behavior (most days). I'm not very intimidating except that they know that I know so much about lots of stuff. I have fun with the kids and look forward to finding some new ways to demonstrate physics. [Coincidentally, I thought of a new way to demonstrate and assess the five properties of light just as I was writing this paragraph. See Chapter III to find out if it worked.] I hope to build on these new feelings to bring physics within the reach of all students in my school, not just the mathematically proficient.

I cannot emphasize enough the importance of writing for my high school physics students. I used writing assignments, as well as the traditional math problems, to evaluate their initial progress. I also needed to find a way to teach the kind of technical writing that is expected by employers and how to have them evaluate their own writing without ruining their desire to improve. Instructors spend endless hours red-marking writing that is largely ignored by students. I wanted to know how the student accomplished the mastery of a chapter. What did I do that enabled the mastery? I wanted to know that the student did master the chapter and I wanted to know how they overcame any obstacle to their understanding. In industry bosses don't care how difficult the project was, only that you produced on time and on budget. The best project engineers learn from all their mistakes, all the bad parts and all the dumb ideas they ever had. These engineers are called "experienced." Students need to learn how to learn from their mistakes and from their experiences in order to become successful in a later occupation. Students' final evaluations should reflect <u>how</u> they have mastered material in physical sciences rather than simple paper and pencil math mastery. Other outcomes may prove to be more lasting and illustrative than the traditional objective testing.

# CHAPTER II

## Review of Reseach Literature

I attempted to concentrate my research in two areas that would produce materials and would relate to the rationale for my project. My first area was to see if anyone really thinks that writing is a useful tool to improve learning efficiency. The second area was to see if anyone actually has used writing in science or math classes as a regular pedagogical strategy. (There, I have used that word once in a written sentence and now my life is complete.)

### Uses of Writing to Improve Learning Efficiency

I was hoping to be inundated with literature by multitudes of teachers and researchers who have had success with this strategy for years. I was disappointed when the wave was hardly a ripple, at least in secondary science and especially math. I have thumbed through many physics and chemistry textbooks to find the same conclusion. We haven't changed our strategy at all. I recall one text in the 1970's that emphasized reading and discussing more than math, but I haven't heard of the Harvard Project Physics text at all in my second educational career.

I was really disappointed with the few articles that I located with a related classroom writing experience as a science or math learning tool. If my stint as an engineer taught me anything, it was to embrace change not to shun it. Industrial technology in any industry completely changes every five years. If we as teachers don't change or modify our materials or methods, we too will become as obsolete as a carburetor, Swiss watches, nonportable phones or cars without air bags and antilock brakes. I spent so much time in my prior job writing such a variety of documents that I thought I would never get to my laboratory to design or build a model with my hands. I have vented enough and it's time to start reviewing the articles that I was fortunate enough to find. I want to extend my thanks to all these pioneers in the field of writing in science and math.

Zemelman and Daniels (1988) began to reinvent writing as a process to learning, not the end product of something learned. Writing is to be experienced rather than a lesson to be evaluated. Writing is to be learned not taught. It may engage unconscious processes and it may be done in any order of drafting, editing or revising. Writing may be silent and solitary or social and collaborative. It may be fast or slow. It's no news that writing improves with experience at every level. It also improves with exposure to more styles of writing and improves as we read our peer's writing.

Sentence mechanics, combinations, and spelling can best be learned using the students' own work rather than taught as exercises and drills in a workbook. Moderate noting of structure errors or patterns of related errors are helpful to focus on the next revision. Evaluation that stresses revision rather than punctuation, praises and asks questions rather than criticizes, will get the best results from students.

This seemed like a good start to a series of books on the process of writing. It appetizes but doesn't fill you up. I need the main course of topics and personal experiences to really gain my confidence in this approach. Fortunately and gratefully, these authors found new strategies for writing in classrooms and presented an improved model in a later book.

Zemelman, Daniels and Hyde (1993) expand on their earlier work to complain about school reform and reformers. They ask why those pleading for school reform have not suggested or requested any curriculum changes. What should we teach and how should we teach it? If reform is so necessary, why are there no suggestions of change to the curriculum? Processes of teaching and interactions between students and teachers are mentioned by a few reformers. Most political education reformers want more testing, more basics and for less money, while mandating more agenda to be taught without providing necessary funding. These authors say that if we are to change, we must change the classical classroom, homework, textbook, workbook and mimeographed handouts that have been the backbone of educational culture for too many years. Doing the same things stronger, harder and longer isn't changing test scores. It seems that test scores are about the only thing that reformers want to see changed. The last test I took was the entrance exam for admittance to graduate school. I never once took a test while I was in business. This book also liberally sprinkled answers to many classic "Yes, but...." questions. Immediate response to the naysayers in our profession(ourselves?) has a neat style to maintain ones reading momentum in a text. Chapters for every subject area are included with several varied activities including writing. Classroom and teaching method modifications are also included in each subject area.

Schools are struggling to find out what works and to define the "best practice" of each subject area. "Writing across the curriculum" and "whole language" are two examples that seem to be working in classes where teachers have received suitable training and mentoring. Even the National Council of Teachers of Mathematics have written new standards for math teaching that are progressive, appropriate, teachable and research-based. Included in the Zemelman(1993) book is a list of what to do more of and less of in our classrooms. All of this sounds a lot like Dewey in the 1930's and maybe even the open classrooms(pod schools) of the 1960's, but this time we really have to thoroughly train our teachers to change their methods without cramping their teaching styles.

Hoffman (1992) was convinced by professional technical writers that all writing, even technical writing, was creative writing. He focused on three objectives in his technical writing course. The first block was to describe people, places and objects. Processes and procedures, such as making a peanut butter and jelly sandwich, followed with hilarious results. Peanut butter and jelly ended up on the outside of the bread, the bread ended up at right angles rather than parallel and the bread was cut lengthwise from the loaf. Simple science experiments were set up and described by the students as if they were explanations from some of the "how do they do that?" books found in libraries (and on coffee tables). The second block included criticism of educational memos and articles. Students had to sift through the fuzz and make sense of the educational vernacular to the embarrassment of their principals and superintendents. Everyone learned that big words did not always convey the intended meanings. The last block was the big project. An audience was targeted, a problem was researched, proposals were suggested, plans of attack were submitted, solutions were suggested and references were listed. It seemed like a research paper to me at first, rather than technical writing, just targeted to a specific audience. He seemed more comfortable with that approach in his class. But, on second thought I agreed with the intent of the research and the group work that finally resulted with the plans of attack and proposed solutions. That was most similar to the usual engineering or manufacturing meetings that I participated in and chaired for many years.

A harried executive who must write an unpleasant report to his Board of Directors in a short time is compared to a student who must write an essay for his teacher in a few days by Fagan (1985). The mental anguish of just beginning the report followed by the revising and editing process of a written report, anticipating and answering the questions before they arise and addressing specific information to just certain members of his board are related in this article. He claims that it is the same process and pressure for every student who is expected to write perfect copy the first time, every time for a teacher on an essay test. Is it fair that the executive has the revising and editing privilege?

We as teachers are continually expected to edit and revise that long, dull textbook into two pages of snappy, hilarious class notes for our students. Well, exc-u-u-u-use me. Who taught me how to revise and edit? I think it was me because I was there in front of the class doing it. And I was deciding how many of those seven intelligences I could include in those two pages at the same time. Our students must also learn do that editing and revising function for themselves in order to remember just the important stuff, the stuff that will be on the test. It is the same thing that we all do to process what we see, hear, feel and do.

Weber(1992) admits to his initial misgivings about technical writing as boring, but soon got over it by developing some realistic tools for his senior English students to write about. He defines technical writing as writing that has only one interpretation rather than the layered meanings and feelings of creative and other kinds of writing. It is writing that goes to usually a very small or a very specific audience. He compares it to advertising writing, which also goes to very specific audiences. Technical writing must be objective, impartial, literal, reader oriented, very technical, completely factual and truthful unlike the emotional advertising writing that we are all familiar with on television or in print. I don't think he has a clue how many thousands and thousands of technical periodicals and newspapers with technical articles and technical advertising really exist out there in the world that publish every week or month. And every one has editors, copywriters and reporters writing technically every day. There are vastly more people in the world of print media and in business writing technically than authors writing fiction. Why do almost all English and literature classes focus on the fiction, poetry and creative types of writing lessons?

Several writing ideas he uses are (1) replying to science questions from letters written by grade school students, (2) describing a simple mechanism, (3) assembling a puzzle from verbal instructions and (4) assembling a model and writing instructions using simple children's construction toys followed by others testing the instructions.

Arnold (1983) writes that if the material in a business report is true, reliable and accurate but not clear, orderly and easy to grasp, then the report is lacking in concrete nouns and action verbs. Vagueness and unnecessary verbiage hinder communication. The best research and data can be hidden by poor choices of vocabulary in a professional report. Further, report writers should avoid emotional terms, list their assumptions and keep their prejudices and preconceptions under control.

I would go further to say that reports should state events as they occurred or seemed to occur, recourses should be suggested or alternatives offered but without the finger pointing to an individual that never solves any problem. I have seen more bad feeling flow in meetings where someone lost it and started to blame another person for insufficient research, failure to anticipate every question or failure to research the material that one somebody else forgot to request. Every product proposal or specification that I ever developed or have read about had multitudes of drafts written before agreement was finally reached.

I reviewed several books that promised to use "writing to learn" or to "write as a career." I was disappointed with their content. They were wonderful books for students who want to become writers. They were books full of how to organize ten kinds of paragraphs, how to research, how to fix mechanics and punctuation. They were good books for a writing class applicable to those who want to learn to write but not for my intention of writing to learn. I wanted books for those who don't usually write except in literature or English class. I need books that have writing activities for secondary science classes, books with topics that can open minds to the richness of science without baffling them with math.

Murray (1993) has lots of writing prompts for kids once they get started, but these helps are for longer writing projects. I just want my kids to write a page or two pages to compare, contrast, describe or relate. I have to constantly think up applications or metaphors to explain physics principles. Why aren't there books to help us do this? Most of my physics books have demonstrations but not verbal explanations that kids could relate to.

Vargas (1986) suggests watching out for first, second and third person in lab reports and being aware of active and passive voice in verb selection. Well, she is an English teacher and she probably grades every one of her student's papers. I don't have the time or the inclination. I'll let my students criticize each other's work after I have established their habit of writing and the trust that their writing won't be graded for grammar. I usually have them read it out loud to each other and the bad stuff gets fixed easily before I ever see it. It is way too early for us to develop lab report styles. I didn't have to learn to write lab report style until I read dozens of engineering reports in industry, which was 15 years after high school.

## Writing in Science and Math Classes

Now we will expose those brave souls who have dared to spit in the faces of their classical contemporaries and try new strategies that include writing in their curriculum.

Hewitt (1994), author of the popular secondary physics text Conceptual Physics, implores physics educators to teach the concepts of physics first before grinding out the math that has been the corner stone of physics curriculum since the 1922 version of Modern Physics. No one disputes the importance of math or the application of math to physics. But most students will never take another physics course, while most will take another math course in high school or afterwards. Why can't we just teach physics concepts to these kids and allow them to learn problem-solving in their math class. Physics today is used to teach problem-solving with mathematics, but physics doesn't require a problem-solving approach to be learned. Physics course content is often determined by "what is going to be on the test." Science educators must give suitable priority to concepts as well as problem-solving questions on their exams. Qualitative questions that require a sentence or a paragraph should be encouraged.

We should realize that there are three basic sciences, biology, chemistry and physics in our world. Practically everyone takes biology, many take chemistry and few take physics. Yet all of us have more interaction with household and lawn chemicals, drugs, electricity, heat and friction, motion of vehicles, energy and electronic technology than we do with algae, insects, photosynthesis and frogs. What is wrong with this picture?

MATH. Fear of MATH. Fear of word problems. Real nauseating, palm sweating, dry-mouthed, adrenaline-pulsing fear of failure in solving math problems.

The new ChemCom chemistry curriculum and the Conceptual Physics curriculum are based on concepts rather than math problem-solving. Since most students will never take another chemistry or physics class again, there is little reason to make every student in the likeness of Einstein or Isaac Newton. By the way, neither gentleman ever took a chemistry or physics class in high school, so we shouldn't even look for their protégés in our high schools anyway. Newton invented most of our physics during his lifetime and Einstein dropped out of high school.

There are still problems to be solved. These can be mastered with the lab experience, the small student-lead group discussion and the pencil rather than the scientific calculator and a trig formula. After all, if lawyers can explain complex legal ideas, scientific evidence and motives to juries of our non-science peers using only pictures painted by words, then we as educators ought to be able to explain and demonstrate the basic chemistry and physics principles to willing students.

Goldberg (1994) lists four reasons to write in her math classes: write for understanding, write for communication, write for learning and write to express feelings. She says that we should write about what we know well, about what causes difficulty, where we are deficient and how we progress towards our goals. The students may personally communicate with the teacher in ways that they would never dare to in front of their peers. And the teacher should respect the privacy of the communication, if it is warranted. Writing encourages more thoughtfulness and analysis, clarifies issues, focuses on simple answers and forms bases for later discussion by both teacher and students. Just writing to express joy, satisfaction, anxiety or frustration is reason enough to unload our feelings.

Writing in math class is limited to simple or single topics, in class or out of class. The short writing lesson may occur at the beginning, middle or the end of the class period for 3 - 7 minutes. Reading the student responses is done the same day with a short comment. The topics are designed to get specific prompts from the kids, so the teacher should know ahead of time what to expect. Suggested writing responses are about half a page. Responses are credited, but not graded, since your goal is find out where the writer is in his thoughts. The students are encouraged to be honest with their replies. I will probably learn more about them and how they learn than they will learn about my topic in class. I plan to be a better teacher for that knowledge. This lady is at the top of my favorite teacher list.

At last someone has asked their physics students to actually write longer than a page. Saltman(1994) has assigned his boarding school students to write a chapter of physics. He doesn't test them with math, but they have to understand far more math than if they had done the problems. Sometimes they worked in groups and they sometimes worked alone. Some of their chapters became stories or narratives. His students edited each other forcing clearer explanations and removing incorrect material from their text.

The teacher began with simple demonstrations of the chapter topic to start their questions flowing. Then the students began to use the teacher as a resource for their work. Illustrations and examples were much different than those used in any textbook. They had to invent problems to solve, experiments to perform, questions to answer at the end of the chapter, but no test. Almost every student showed an ability to shine in one area or another. Cooperative skills and leadership skills were developed. Teachers were cautioned not to make the topics too broad for the students' first attempt at writing. The students were very proud of their work at the end of the project.

This article got my attention. I will attempt to have students write a chapter section, rather an entire chapter, due to my class sizes. My next chapter luckily is on kinetic theory of matter which has little math and has dozens of applications of physical properties of solids, liquids and gases. I have essay tested this unit in both my prior and current teaching careers. Now I want to try to teach it with writing, rather than test it. I am eager to try this method, take my lumps and learn how to really do it the next time. Experience is the best teacher and it's my turn to learn.

! think we will start with a take home experiment using a version of the collapsing can experiment from Hewitt (1992). Nissani (1994) uses soda cans, instead of gallon cans, heated on the stove and dunked upside down in a sink full of cold water to collapse or crush a soda can using just the temperature difference only. It's an impressive demonstration. Instructions are given to the students in class. They are to write their predictions in class before trying the lab at home. After the lab is successfully completed, the students write their observations and try to explain what actually crushed the can. I can bridge this demo to my experiences in my PADI scuba diving classes, air conditioning system design experience, psychrometry of air properties, refrigeration principles, airplane and helicopter flight and how the Carrier Dome in Rochester, NY is supported by air pressure.

Maybe there is some more help from Connolly and Vilardi(1989). The use of ordinary language in teaching of science and math enables teachers to connect thoughts, insights, facts and understandings to experiences in the everyday sense. The young person of today has become unfortunately dependent on the gadgets of our lives: CD's, CD ROM's, computers, cellular phones, remote controls, microwaves, CAT scans, satellite communications, lasers, CNN, Nintendo's, Gameboy's, Walkman's, boomboxes, video games, cash registers that make change, bar codes to enter everything, digital everything and the information superhighway. Kids today never owned a record. They totally ignore the space shuttle launches, unless a tragedy occurs. They never remember smallpox, polio, TB, life before paramedics on the fire trucks or the days before heart bypasses and organ transplants. We have all come to expect a lot from technology these last ten years. But which of us can say that we understand how any of it works in any language. We will all become technology idiots, totally dependent on technology to make our decisions for us if we allow it. It seems that with every layer of technology that is heaped upon us, the will to understand it becomes more distant and irrelevant. I couldn't agree more.

## Summary

It seems that we ought to be teaching kids how to understand, how to decide and how to ask questions, rather than how to learn formulas and facts for the test on Friday. Science and math will become even more polarized in the future because most people will not be able to understand or explain the technology. It seems that one solution is to give all learners a command of ordinary language, speaking and writing. We as math and science teachers need add this strategy to our arsenal of tools with which to teach science and math.

Some public policy has turned away from science such as the cancellation of the superconducting supercollider, the cancellation of the space station, cutbacks at NASA and the Department of Defense, decreases in medical research and an increase of environmental concerns due technology. The public is lackadaisical toward science, but very hip to consumer technology. We don't realize where the technology came from. We expect a lot from newspaper reporters, TV commentators or magazine editors. We look and listen to them to summarize everything we ought to know about what's new, what are problems for society and especially what wrong with education. Well, who died and made us worship them as experts? And who taught them the science and the math to be able to explain it all to us? No one, if they didn't take the classes. We will all die a little if they are allowed to fill in the vacuum we have cultivated (or is it composted) between our ears.

We need a sorbet for the mind while I step off my soap box before transitioning to my next article. I will now focus on several activities that I can incorporate into my daily classroom curriculum. So cleanse your thoughts for the gentle downward slope to the end.

In science we use three kinds of writing: transactional, poetic and expressive. Transactional language is used mostly to instruct, inform or persuade and occupies most of our writing. Expressive writing or freewriting is like thinking out loud on paper and is closest to primal thought, yet least used in schools. It's like a diary or journal writing. Poetic writing gets more time than expressive because feelings, emotions and insights are released to paper in this style.

Transactional writing includes writing summaries, questions, explanations, definitions, reports, word problems and personal notes. Freewriting is encouraged for 3-7 minutes at different times during class. Freewriting is ungraded, uncriticized dialogue about what you didn't understand, what was the most muddied issue in class, what bothers you most, what were the main ideas, what were the relationships to other lessons, how might you apply this lesson or what metaphor could describe this lesson or concept? Mechanics, spelling and grammar aren't counted, nor is penmanship. Questioning, commenting, agreeing, disagreeing and praising are things we mark on these papers. Dialogues between students may develop if the exercise lasts more than a few weeks. Teachers should share their writing with their students to promote camaraderie.

Suggested exercises that I have digested throughout all the books I have reviewed include: 1) relate a current topic to a student's prior knowledge or to a previous lesson, 2) how to solve a problem that has multiple correct solutions or no foreseeable solution at all, 3) write a logical order process to the assembly of some simple thing such as a peanut butter and jelly sandwich or assembly of some lab materials, 4) write a process to show how to prove or how to measure a science statement, a physical constant or a formula, 5) write the sources of error in a lab process, 6) write out several test questions, true-false, multiple choice, fill-in-the-blank or matching, 7) write out several word problems with their solutions, 8) devise a metaphor, verbal or pictorial, to explain a concept or 9) just write about what you thought I was trying so poorly to say.

Finally, I know that I must start my students writing in physics from the very beginning of the year. The habit will not be any adjustment for them as it will be for this year's students. Last week I tried having my classes write their entire chapter test. Groups of 1 - 5 wrote and developed a two page test using five different kinds of test questions. They provided the correct answers on a separate sheet. They spent two days on this project. Their questions were overwhelmingly fair, with a good level of difficulty, well written and covered the chapter adequately. Most of the students liked it better than my usual test and said they learned just as much as if they "had really studied." I just smiled knowingly in agreement.

# CHAPTER III

## The Study

For those who skipped ahead to this point, I will explain my study again. For the persistent, I will explain it again using even more examples. I am incorporating writing as a tool to master the concepts of physics. Traditional teaching and learning in physics has relied on the mastery of math applications and formulae as the basis for assessment. Well, this has scared off too many otherwise intelligent students who need to know much more physics than they will pick up on the Mr. Wizard Show. Physics mastery does include some math, but most of it can be learned by common sense applications of things students do every day. Students write every day and this method will help them figure out successfully what they must know to be successful citizens in our technological society.

It is incredible that with so much technology in our world, we still insist on a full year(147 hours of instruction) of biology, a year of chemistry (in our district as of next year) and **NOT 10 MINUTES** of physics. I regularly tease my biology colleagues about their subject matter. One week it was the "life cycle of moss," another week it was "the 6 characteristics of algae," then "the structure of sponges" and still another was "how mushrooms procreate." I've seen worms procreate in my garden and it wasn't romantic. Now, it's the end of the year and they are have to skip the chapter on fish to make time for birds and mammals. We make time for these subjects in our school requirements, but no time is required for the science basic to the other two required sciences. The biology teachers retaliate by calling me "biologically impaired," but out of all the other science teachersin my school, I am the only one who has a vegetable & spice garden and a working compost pile at home. They have no response to my rebuttal. I have had 6 or 7 jobs in my career and would never dare to list my biology experience on any of my resumes. But chemistry and physics experience seemed to interest every one of my employers. Perhaps the time spent on biology could be spent on more useful biology than I have seen this year.

There is no time to teach the transformation of energy in plants and animals, the chemical or heat-related processes of digestion, the energies and chemicals consumed and replaced by plants and animals. These are physics related topics. Physics is the study of energy; mechanical, gravitational, chemical, electrical, magnetic, and nuclear. Physics is the basis for all the technological applications that transform energy from one form to another in the forms of photosynthesis or photoelectricity. Yet we discriminate against ALL STUDENTS towards physics because it was traditionally MATH and MATH WORD PROBLEMS. Physics was only for the mathematically competent, an elite society of students, usually boys, usually white boys, who were pushed into higher math classes to be engineers or doctors. Homemakers use more practical physics every day than all the word problems that were ever solved in the name of traditional physics classes. I wish that diet woman would find another slogan so I could shout, **"Let's stop the insanity !"** without sounding like a cliché.

## Setting for the Study

The study took place in the physics classes at East High School in Rockford, Illinois, during the 1994-95 school year. East, student population of about 1750 students, has three traditional physics classes and one non-math or conceptual physics class. There are a few second year physics students sprinkled in the regular physics classes working primarily on an independent study basis.

East is located in southeast Rockford in middle class and working class neighborhoods. There are some working poor families, but not many upper class families. Our neighbors are ethnically mixed as is our school with about 30% minorities, including African-Americans, Hispanics, Asians, and Native Americans. There are few bussed-in students from outside our neighborhoods, unlike the other three high schools in town with large bussed-in populations.

East is the only remaining high school with a large parent alumni population in town. That population( in the name of the Booster Club) has a large influence on the attitude of students and how they relate to each other. It is a very positive influence born out almost 50 years of school pride. The other large alumni high school was closed five years ago to save money. That closure resulted in filing of a huge discrimination of minority student lawsuit against the school district. The district was found guilty and is in the midst of proposing the remedy to the federal judge. I will not go into the lawsuit in this paper; it is a whole book unto itself. The lawsuit was good for all the students, but extremely traumatic for the community.

My physics students are among the best students in this school, but many other good students are missing this science due to, I believe, the math content of the traditional curriculum and lack of a third year of science requirement for graduation. But our local board and administration think that only 40 credits of high school fulfills the requirements for a diploma. This is the lowest diploma requirement anywhere and they know it. The school board is not especially proud of their number, but wanted to increase the graduation rate of our students several years ago.

I don't see the school board raising graduation credits due to the increases in numbers of high school classes, staff, funds, equipment and facilities that would result from that change. So, I guess the way that I have to reach kids is through the grapevine of former students who have had good experiences in my classes without the pain of constant math. Writing is one of my new tools to teach students the science of physics.

## Research Procedures and Methods

In chapter two I enumerated many ideas on how to write, when to write, what to write on, how long to write, what to grade, several kinds of writing and a few writing projects. Now let's get to the mechanics(good physics word) of the study.

I originally examined portfolio writing as a tool to assess and implement student writing. In Student Portfolios Daws(1993) wrote that portfolio implementation was a slow and evolutionary process. His portfolios were not connected to any essential outcomes, even after three years of use in an alternative high school math curriculum. Few insights were mentioned regarding his curriculum modification for portfolios and his lack of connection from the portfolios to the desired outcomes. I felt his frustration could be due to lack of training in portfolios or the lack of empowerment to be able to connect to math outcomes. I do commend his perseverance to his beliefs to try for three years to "make it happen" for his students.

Biles(1993) in the same book immediately began to evaluate portfolios after a state-mandated portfolio assessment became effective. Prior portfolio training and experience proved to be helpful for this instructor. Colleagues without training had difficulty adapting to portfolios. However, the students did not adapt to the portfolio evaluations until the local board of education made 12th grade portfolios a graduation requirement. Their portfolios were finally evaluated and given one of a set of ratings. The ratings were novice, apprentice, proficient and distinguished. It would seem that many teachers and students resisted the mandate and that the mandate was implemented too quickly without prior training for all instructional and administrative staff. The four ratings seem reminiscent of letter grades. I wonder if the students' transcripts have an interpretation of the ratings? I wonder how colleges responded to those four ratings, rather than the traditional letter grades?

Krest(1990) could not handle the portfolio paper load in a secondary English class. Assessments took place without reading everything that the students wrote. They were done on selected works of the students after peer review of the papers. Student's grades were determined by a combination of risk taken by the student and the student's grammatical and mechanical progress in their writing. About twice the weight was given to the risk factor in the final grade. In industry no project is ever submitted for manufacture without weeks of peer review. Even pay raises are subject to the amount of risk taken and overcome in the completion of a project. This method seemed to be born out of necessity and modified to the ultimate benefit of the students. This method appears to be a realistic approach similar to many other professional evaluation processes.

Other authors were more encouraging than those who attempted portfolios. There seems to be a wider variety of things to try with the next two authors.

Student writing should not be evaluated with the "red pen" suggest Zemelman and Daniels(1988). The red all over the page just demeans, offends and insults the effort of the student. The teacher's time was wasted correcting errors because the students only wanted the summative outcome, the grade and a feedback comment, not the corrections. Writing feedback needs to be positive, especially in the first drafts. Writing teachers should try to coach, not judge or edit, in the early stages of student work. Since the teacher already knows grammar, why not have the students evaluate their peers' grammar? That is what peers are for in the workplace.

Writing could and should be a means rather than an end for learners is a message from Stover, Neubert and Lawlor(1993). Writing briefly at the beginning, in the middle or at the end of a lesson assisted the students in summarizing, applying, predicting or recording observations of their learning. Both the students and their teachers benefited from the feedback of ungraded, but inspected and credited, student writing during the timely and brief writing lessons. This tool seemed to be best use of time for both student and teacher. With experience, a teacher could grade a class of paragraphs in less than half an hour. More study is warranted to maintain the benefits of this method. I'd bet that some regular student-teacher written dialogue also takes place in this method just as it did in my graduate classes.

These preliminary tactics to writing were not the best directions that I was hoping to find. It seemed that the way to begin was to just try assignments that I was comfortable with in my classroom. Engineers are supposed to assume risk by trying new things. So, I did try as many of the methods that were suggested by others as I had time to "read". (I wrote "grade" the first time because I had to remind myself NOT to grade the writing.) I did learn that "reading" and commenting takes time and that it has to be timely, like the next day, or the effect was limited. Then there are always 2 or 3 stragglers and absentees per class to find time for in the next day.

The students wrote criticisms of Carl Sagan videos about the origins of the universe, the lives of the stars and things that even Einstein didn't know. They wrote their own examples of a "system" after I lectured about the First Law of Thermodynamics. They wrote for a test question HOW they learned the First Law of Thermodynamics and gave an example. They drew pictures of the states of matter, solids, liquids and gases, using everyday objects rather than molecules. They had to describe the pictures. They wrote their own tests with their own true/false, multiple choice, fill-in-the-blanks, word problems and essays with complete answers. They used books, old homework, others at their table to help write their tests. I slowly learned that any good paragraph in physics should have a picture or illustration with it. So, I started requiring graphs, charts, diagrams or illustrations with their writings. The art wasn't great, but it used another part of their brain. I asked if some of them wanted to do a skit to demonstrate the five properties of a wave. (I remembered "the wave" from college football games and wondered if they could figure out the other four properties with humans.) We wrote about personal experiences with evaporation, the number of thermometers and thermostats in their homes, the number of springs in their homes, the appliances that use the most current and how to dissect an ap ance( like they dissected a frog in biology class.) The possibilities that were unknown at first have blossomed into more than I can handle with my classroom work and this research project.

There doesn't seem to be a plan or a method in this project except that in engineering, as in other disciplines such as education, ONE THING LEADS TO ANOTHER. This is how most things are invented by engineers, doctors, researchers and teachers. We take the road that seems to lead us to our desired result. Eventually, we achieve our desired result by our perseverance or else we run out of time or enthusiasm and settle for what we have so far. Everything that we have and every process we use was invented by some one who thought we needed it or could sell it to fools like us. Trust me, someone would have eventually invented white out, soap scum remover for the bathroom, post-it notes, chalkless blackboards and twinkies. Therefore, any soul that wants to adopt writing as a tool for their classroom can decide to do it and figure out a way to do it well. Most of the credit goes to the kids who did these assignments without any hassles or arguments. Sometimes the students actually follow the directions they are given without complaining.

## Findings

It was especially gratifying that the students looked forward to these writing assignments, rather than have the same old multiple choice tests or more hard word problems that they take forever to solve. My classes are very relaxed. No one asks to go to the bathroom; the hall pass is on the desk for anyone that needs it. Kids always can have a pass to see their counselor if they write it out themselves (but I always sign them myself.) Kids talk quietly to each other at their tables during pauses in my notes and during the homework explanations. It's not my gilded remarks nor my concise notes nor my ingenuitive problem-solving technique that enables their learning, it's their continual iterative review and explanation among themselves that seems to have the most effect against the background of my work. Their learning is far more auditory, synthesizing and analyzing than I ever realized. Learning can be enhanced by more kinesthetic activities besides labs, such as activities to demonstrate velocity and acceleration, height of trees and the smokestack, making ice cream in a baggie, bottle rocket and model rocket launches, paper airplane day in the big gym, an egg drop off the top of a three story building, a household appliance dissection or building a bridge with toothpicks or balsa wood and then loading it until failure. These projects were bonuses to the original plan of just doing more writing in and out of class.

Since I'm supposed to evaluate my students' performance in physics, I used writing and other tools to test their learning. I gave objective tests, all essay tests, group tests with a variety of questions and make-up-your-own tests. I asked them to rank the test by preference, figuring they would choose the type in which they did their best work. I received all sorts of replies.

Most did not like or prefer objective tests due to boredom, not knowing what would be asked, not having time to finish and not having time to study for them with all their other homework. Nobody loved the essays entirely, but many preferred to take them home to work on them for several days including classtime. Some hated essays because they see themselves as poor writers. Some really liked my questions and gave their answers a great deal of thought. My essays were limited to 2-3 paragraphs per question and some wrote well in just one paragraph. Length of writing seemed not to be an issue, but writing confidence, even with their book available, bothered some students. These same students were also poor objective test takers, too. However, almost everybody liked the group tests and the make-up-your-own tests. The slower students thrived in these two methods. They cooperated wonderfully in their self-made groups, the people at their tables. I never assign seats or groups. These were the most authentic projects they have done that relate to "real work." If I hadn't told them it was a test, I don't think I would have gotten the same intensity toward task completion in a timely manner. The group tests were harder than my usual one period test, and required more time which was granted. The make-up-your-own tests were exactly that. I told them how many questions and types of questions to make up, including the correct answers of course. I threatened to have them exchange tests to see if they could pass each other's tests, but did not follow through because they took too much time to write and edit their own tests. They were easy to grade and much better written than I ever imagined. I guess they have taken enough tests not to be too unfair. Most liked that "kind of test" and said that they learned more on that test than they had learned in class. I could have told them that because they never read their book. They look at their notes the night before or the hour before their traditional tests and hope they pass. That style of studying is becoming the predominant mode of test studying.

For their final exam I will assign them a project to complete. It will be to design the safest automobile, the safest, lawnmower or tractor, the safest bathtub and shower or the safest playground. The project will have to include use of existing facilities, cost proposals, features to prevent injury, how to test for safety, safety standards, changes to existing lifestyles for safety reasons and anything else that would be necessary to make their ideas feasible. There exist many good answers for these kind of projects for the students to demonstrate their combined knowledge.

Other writing assignments I gave were video critiques of some of Carl Sagan's Cosmos series pertaining to Einstein's theory, lives of the stars, and the four forces in the universe. I gave these assignments when I was gone on professional leave. The students seemed to blow the assignments off due to the substitute teacher. I will plan to be there next time I show these videos. Sometimes I assigned short paragraphs on a single concept that I introduced that day. I allowed and encouraged sketches or drawings to enhance the paragraphs. I usually asked for examples or applications of the concept. For example, the first law of thermodynamics is a conservation of energy law. Where does an animal, plant, machine or human get all their energy? Where does it come from? How is it converted? Where does it go? How is it used? How is it wasted? I used a stapler as my example, they got the idea and wrote for 10 or 15 minutes. The stapler was just the closest machine and very simple to explain. These assignments worked very well as part of overall series of activities including the usual questions and problems at the end of the chapters.

Maybe it is the variety of assignments and my use of everyday applications that keeps the students interested in the subject, but they thrive more on learning if there is a chance they will "get it" sooner rather than later and if there is an "activity" involved. Maybe that is why next year there are six physics classes up from four the last two years since I began teaching at East High School.

Conclusions and Recommendations

The top students will learn in any circumstances. Those are the students that usually take physics classes. Recently I had three Austrian students visiting my classes with their principal. They are taught physics for TEN YEARS while in the United States almost nowhere is it required for TEN MINUTES. We need to teach physics to everyone, not just the mathematically elite. My goal is to make physics less mystifying, less frightening due to math and more accessible to every student.

I have learned an overwhelming amount about how kids want to learn, about how they want to be taught and about how they want to be treated in school. It isn't just the writing activities, the applicable math problems, the outside activities but the attitude that if something really is important, show them its importance rather than demand they learn. Kids will do whatever is reasonable for their own learning. They will usually do it on time but not always. Some kids need two days for a one day test. Some kids would rather make a poster than write an essay, so ask them to do their poster and write a short essay. Some kids will never get trigonometry, but most of the world doesn't need trig, nor is it required to understand physics.

I relish the opportunity to try all these things in the time of a school year. Even next year will be easier than last with the demonstrations that I have written already. My presentation of material will include more writing and more physical activities than this year. Tests will still be a variety so they won't get used to the types they like. Some of my students actually look forward to my tests this year because it will be something different. So I must keep inventing different things to attract them to my classes. A list of activities with short descriptions that I have used is posted in the Appendix. I don't think I have even scratched the surface of things that I could try.

About writing specifically, always have the students write in their own words. Allow them to use first person or any other person they want. Don't critique their writing unless the sentence fragments and run-on's are bad. They won't learn from your grammar and you don't have the time. Just underline anything that looks wrong and suggest to the class that underlined stuff might need editing. Allow allegory, metaphors, similes narratives or any form that they want to write in. It's a lot less boring than grading 100 papers on the kinetic theory of matter that they rewrote from the most boring text in the universe. If it isn't correct physics, then suggest changes to the content to help them get it right. I have compiled a list of useful writing prompts that helped get the students started in the writing process. They are posted in the Appendix.

The biggest problem is their handwriting. If they can't write neatly, MAKE THEM WRITE LARGE. And then it won't always be wonderful. If you deduct points until they write large enough, they will succeed eventually, with all their points. Identify those few people early and hound them all year.

Finally, I will conclude with some thoughts I read from Leon Lederman, director emeritus of Fermilab and professor of science at Illinois Institute of Technology(1995). He says that high school physics is a disaster in most American schools. And it has been that way for 100 years. We teach biology, then chemistry and lastly physics which scientifically is the opposite order. Only a few schools in the United States teach physics and chemistry first, as is done in European and Asian schools. Something is in the wind to give hope to physicists now. Superintendents of schools in New York and Chicago have announced their intentions to require THREE years of science and math for ALL students. Science curricula will have to change to reflect technology, society and relations between the sciences. Physics will have to change from the junior-senior elective course to a freshman level conceptual course, algebra-based. And fourth year science classes can be prepared for future Congressmen and TV anchorpersons. Science curricula might be a three year progression of topics rather than separate classes of physics, chemistry and biology. The catch is that there aren't enough physics teachers to do this, not even close.

On 21 February, 1995, the Chicago School Board approved the plan for implementing a three-year math-science requirement by 1998. Look for others to adopt a similar plan very soon. Let's hope we get the order right for the next hundred years. Physics Phirst !!

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# APPENDIX A

# WRITING PROMPTS

WRITING PROMPTS: Writing ideas used to begin a lesson, finish a lesson or begin any assignment. Use any amount of time you desire. Write at the beginning, the middle or end of class. I use 3- 7 minutes for most ideas. I **NEVER** grade grammar, spelling or penmanship. I **ALWAYS** make some comment on each paper, usually brief and positive, sometimes prodding and longer. I'm looking for communication, prior knowledge, understanding and feedback, not just comprehension.. Everyone gets 5 points for these papers, no deducts. This list never ends once you get started. I hope it helps you to start using writing as a tool to concept understanding. These are in no particular order. Fill in your own words to finish the prompt for your class.

I didn't understand before but now I understand ....

I am still confused about ....

I am really frustrated about ....

I really liked the part about ....

I least understood (or didn't get) the part about ....

I wish you would explain more about ....

I had no idea before today's lesson was how that worked or that was used for. I thought it was used for ....

An example of today's lesson at my house is ....

A metaphor, allegory, parable or simile of today's lesson would be ....

This is off the subject, but I wish sometime you would explain about ....

I agreed with the part about ....

I disagreed with the part about ....

I never thought I would like ....

I never realized how important it was to know ....

I thought we would never finish ....

I thought that I would never be able to ....

It is so satisfying to be able to ....

Describe every step in the making of a peanut and jelly sandwich. Exchange papers and have others critique the procedure for misunderstanding. Often the PBJ ends up on the outside of the bread.

This lesson was most like the other lesson that showed ....

How would someone measure the results of this (concept, formula or lesson) ?

How would some one test the results in this lesson?

What earlier idea could this lesson be compared to?

Write down in 3-7 sentences what you thought I was trying to say.

I think today's lesson would be best applied to ....

I solved today's problems using these methods.

I tried to solve today's problems using these methods, but they didn't work.

This is how I finally understood the assignment. Describe exactly the example, the problem, the explanation or concept that allowed understanding to occur.

# APPENDIX B

# LESSON ACTIVITIES

LESSON ACTIVITIES: These activities are used throughout the year in various chapters or whenever I decide to try them out. Some are assignments, some are labs and most are for "controlled excitement."

1. Write your own test. Make up 2-3 multiple choice questions, 2-3 true/false questions, 2-3 fill in the blank questions(have them fill in the blank with a wrong word that needs to be corrected), 2-3 word problems, 1-2 short paragraph essays or 1 longer essay. Some opted for some matching questions. They worked in groups of 1-4, depending the individuals. They used any books, notes or homework that they could find. Complete answers must be provided. Tests could be exchanged if time allows. My students took 2 days in class to complete the assigned task and some took it home the second night to type or recopy. Almost everybody got full credit for their work. Absentees are a hassle, but they can be assigned shorter tasks or be give more time.

2. Write a story, a play, a skit, or make a poster or diagram about the assigned lesson. Some laws are so obtusely worded that one can only picture the law in your mind's eye. Characterize how you "visualize" the material in this lesson. Newton's Laws of Motion, the Kinetic Theory of Matter, the Ideal Gas Law, the Special Theory of Relativity, the properties of waves are sources for these activities. One group did a skit in the hallway about the five properties of waves using their classmates in the skit.

3. Demonstrate position, velocity, acceleration, change of direction and vectors on the football field. Have students stand, walk at one yard per second for 15 sec, wait 10 sec, then walk back for 20 sec while others keep track of elapsed time and position. Graph their motion of distance(position) vs. time. Then do a harder sequence and graph. discuss what they "felt" about velocity, direction and position as they observed themselves. Then have them walk five yards in ten seconds and without stopping, increase the yardage by one yard in every successive ten second interval. This helps the kinesthetic learners to visualize these concepts. This also tires them out fast and they understand acceleration intimately.

4. Measure the height of tall buildings, trees, flagpoles, goal posts by proportion to shadow length. Measure known, accessible objects and their shadows. Then measure the shadows of the tall objects. It gets them outside on nice days in the fall. Beware of the bees who are quite aggressive this time of the year, especially around the trash cans.

5. Build model rockets from kits purchased from the Estes Model Rocket Company. Easy ones can be assembled in a day. Others can be painted and assembled in 3-4 days. Most hobby shops have a display and can help with large orders. Use the football field or a park. Check with local authorities (fire department) about permits, if necessary. Estes rockets aren't fireworks, but it doesn't hurt to notify someone in case a

neighbor calls. The rockets are harmless and there is no noise or report.

6. Build balsa wood bridges. There are any number of books at the library with bridge pictures and bridge designs. The ones suitable for this project are the steel bridge designs. I let the students design a bridge 14 inches long(for a span across a 12 inch gorge) and 2 to 2.5 inches wide. I limit the wood use to 4 or 5 lengths of 30 inch balsa wood( 1/4 x 1/4 or 1/4 x 3/16 size). Use wood glue and straight pins to secure the pieces while drying. Then attach weights to the bridges to see whose bridge will hold the most weight. This is a long project taking a week of class time. Drawings have to made to support the design. Daily notes have to be made to note progress. A report of bridge designs or on bridge failures could be done to enhance the background. The Tacoma Narrows Bridge collapse is the most famous example.

7. Hold an egg drop. Students design a shoebox with packing or suspension materials to defend an egg against breakage from impact after its dropped from a high place, 30 to 35 feet is about optimal. I allow anything on the outside of the box, including wings, parachutes, steamers, balloons or "legs." I disallow any form of foam rubber, crushed paper, live or recently dead animals, colored liquids, flammable liquids and oil on the inside of the box for various reasons. I give certificates for best types of designs. It's a fun day in the spring near the break. I require a page about the design with a sketch of the device.

8. Dissect machines. In biology they dissected worms, plants and maybe a frog. In physics we should dissect machines to see the material, electrical, mechanical, structural, assembled complexity or simplicity of common household appliances. Examine every part for how its used in the machine, material, ease of manufacture or assembly into the machine, size, estimated life cycle, wearability and cost. Make a large poster of the machine to diagram the location of each part before dissecting, just like in biology. This could be done early in the year to stimulate thought or later in the year after they know about friction, scaling, materials, and electricity. Ask other teachers, parents or appliance repair shops for parts. You will need lots of small hand tools and drawing paper. **NEVER DISASSEMBLE A TV OR MICROWAVE UNTIL YOU DISCHARGE THE HIGH VOLTAGE CAPACITOR SAFELY.** A severe electrical shock may result, even if the device has been unplugged for a month.

9. Have a paper airplane flyoff. There are about a dozen books out there, some of them are in any large bookstore about how to fold and fly paper airplanes. I xerox a few good designs and let the students wear themselves out flying them one day in the big gym when the PE. classes are outdoors. Don't use ditto paper. Use a heavier grade of paper for best results. I use a 80 to 100 lb. stock that is in reams at the office supply store. It usual use is for fancy resumes and business stationery.

10. Shoot off water rockets using PLASTIC 2 liter soda bottles(take off the black bottoms, if present.) Several scientific companies sell the launch kit for about $20. You have to provide the pump. The 2 liter PET or PETE-type plastic bottles are designed optimally to hold pressure up to about 200 lbs when new. So, don't pump them beyond 60 to 70 lbs when half full of water because you don't know where they have been since they were new. Stand back a little when the water shoots out. Some go over 100 feet in the air. You could demonstrate Frisbees(angular momentum), boomerangs, golf balls with and without dimples, footballs, balsa airplanes and curving wiffle balls at the same time. Save this for a nice day when they are nuts to go outside. I have a rubber band launched helicopter, too. Walmart has all the stuff you need for about $20 to $25 total. If you ever get them back in the room the next day, have them describe in writing or orally as a 5 or 10 minute demonstration how those things work. If you play, you gotta pay.

11. Measure the rolling friction of a car on a level parking lot. Tie a rope to a secure place on somebodys car so it can be safely pulled forward in neutral. You need a 50 to 100 lb. scale attached to the rope to measure the force and you need the curb weight of the car. You may measure the starting friction and the rolling friction, if the scale is large enough. Otherwise, slowly start the car moving to measure the torce that just keeps the car rolling. Its surprisingly low for the weight of the vehicle. Then calculate the rolling friction. I have not done this yet, but I have

read about it in the Physics Teacher magazine. Then research the remaining forces that use up all the gas your car uses. There was an article by DeCicco and Ross in Scientific American, 271(6), 52-57, about modern auto efficiency. That's December, 1994.

12. Figure out the energy consumption of a human body for a day. There any number of references that give the Calorie or joule\hr outputs of a typical human engaged in various activities from sleeping to sprinting. I found a list in the CHEMCOM, Chemistry in the Community text that is widely used. Have everyone write keep track of what goes into their mouth(body) for a day or two and keep track of EVERY activity and length of time at that activity. Calculate how much energy is used for work and how much is used just to keep the organism running. Apply this calculation to the first and second laws of thermodynamics.

13. Make hand made ice cream in a baggie. See Attached. This helps to "see" latent heat of fusion and freezing point depression actually in process. We don't write this up, but we do explain it. It's mostly for fun.

## CHEMISTRY OR PHYSICS LAB

HAND-MADE ICE CREAM

NAME ______________________________

OBJECTIVES: To make ice cream by hand and to show how to freeze milk with salt and ice. And to show latent heat of fusion and freezing point depression of a solution.

***SAFETY RULE: DO NOT EAT OR PLACE ANY CHEMICALS FROM THE LABORATORY IN YOUR MOUTH (UNTIL THE STUFF IS FROZEN.) GOGGLES AND APRON ARE NOT REQUIRED.***

EQUIPMENT & INGREDIENTS: per set-up
Gallon sized zip-lock baggie
Sandwich sized zip-lock baggie
Double handful of machine-made, store-bought, ice cubes
Table salt, about a handful (2 or 3 TSP, more is better than less)
1/2 cup of milk (2% or whole milk, not 1% or skim)
2 TSP. of sugar
1 tsp. of vanilla
Additives(optional at your own risk, but worth it): chocolate chips, M & M's, Gummy things, nuts, chocolate powder, thick fruit jam, BUT NO COOKIES or anything that will become mushy in the mixture. Best when added at end of procedure.
Spoons are mandatory, dishes are optional
Large tub, several buckets or a sink

1. Set up an assembly line: ice, big baggies, and salt together. The rest of the stuff separate.
2. Place the ice and salt in the BIG bags. Set them aside.
3. Mix the milk, sugar and vanilla in a bowl or **go to 4**.
4. Pour the milk, sugar and vanilla into the SMALL bag carefully. Leave some room in the small bag for expansion of the ice cream. The liquid will almost double in size when it freezes. SEAL THE SMALL BAG WELL AND CHECK IT TWICE.
5. Put the small bag in the big bag and SEAL the BIG bag carefully, leaving just a little air space in the big bag.

6. Massage the big bag. Gentle squeezing and rolling over is the proper procedure, as rough handling might open the bags. When there is liquid in the bottom of the big bag, watch for the little bag contents to start freezing. 10 minutes is about right, but longer is better. [If it doesn't start freezing in 10 minutes, check the ice/salt ratio in the big bag and add lots more salt to the ice to restart the freezing process.]
7. Massage/knead until the small bag is completely icy.
8. Let all the small bags sit together in a tub or bucket of ice to further freeze a while or **go to 9**.
9. Carefully remove the small bag from the **COLD**, slushy, salty, liquidy large bag. Here is where the tub, buckets or sink will be real handy. Open the small bag and add the optional ingredients from above. Stir them around a little. Then use the spoon to move the frozen stuff into your mouth. Eat right out of the bag or wimp out with a dish.

Save the large bags for another time. Have a couple of extra large bags handy because there always a couple of leakers around. Just put the leaky one into the extra bag and let them keep on massaging. Wash up the salt water before it dries into "table salt." You will know what I mean if you let it dry on the table.
Remember how much stuff you used per class so you won't have to guess next time. [ I used a pound and a half of salt, just over a gallon of milk, a pound and a half of sugar, 4 or 5 oz. of real cheap imitation vanilla flavoring and two 7 lb. bags of ice for one of my 24-student classes.]

POST-LAB QUESTIONS:

Look up in your book or another book, if necessary.
What is a mixture? ______________________________
What is a solution? ______________________________
Is ice cream a mixture, a solution or both? ______________
What temperature was the ice? ______________________
What happened to the ice when the salt was added?
______________________________________________

Where else do we use salt to do the same thing?

______________________________

What was the temperature of the ice/salt mixture? __________

Was it lower than the temperature of just the ice alone? ______

What action did the massaging of the bags accomplish?

_____________________________________________________

What was the final temperature of the ice cream? ___________

What is the one ingredient in ice cream that gives it the smooth, creamy flavor? ____________________________________

Why do you suppose that some ice cream is so much more expensive than others? Compare Ben & Jerry's ice cream to a store brand.___________________________________________

_____________________________________________________