INQUIRY PHYSICS

A Modified Learning Cycle Curriculum
by Granger Meador
MEADORFIELD LLC

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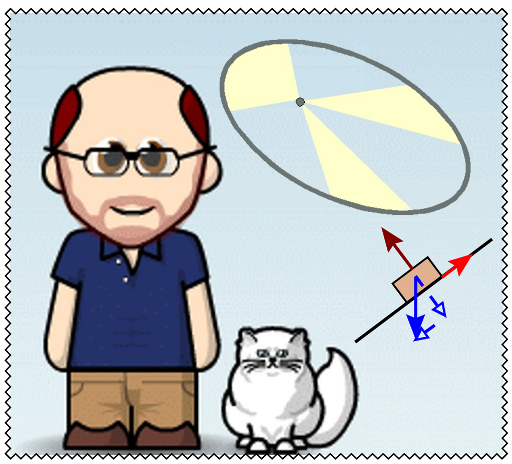

Mr. Meador and Phluffy the Physics Feline

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A Modified Learning Cycle Curriculum

by Granger Meador, B.S., M.A.

BASED UPON:
Renner, J.W., Nickel, J.A., Westbrook, S.L., and Renner, M.J. 1985. *Investigations in Natural Science: Physics.* University of Oklahoma, Norman, OK

This curriculum is a product of my tenure since 1989 as an instructor of the physics courses at Bartlesville High School in Bartlesville, Oklahoma. First published in 2000, it was extensively enhanced and updated for this 2010 edition. The curriculum is designed for students who have successfully completed a first course in algebra, and thus stresses quantitative algebraic skills as well as the development of physics concepts. Extensions are included for students, such as those enrolled in Advanced Placement Physics B, who will be using triangle trigonometry and vector cross products.

Much of this material is a condensed and altered version of the investigations originally developed by the late John W. Renner, Professor of Science Education at the University of Oklahoma, and various science teachers at Norman High School in Norman, Oklahoma. I am also indebted to William Fix, mentor and former chemistry and physics instructor at Norman High School, to Lynne Shaw, former chemistry and physics instructor at Bartlesville High School, and to Dr. Edmund A. Marek, Professor of Education and Director of the Science Education Center at the University of Oklahoma. Any errors in these revised investigations are entirely my responsibility.

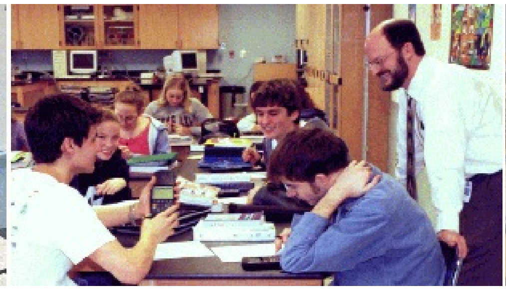
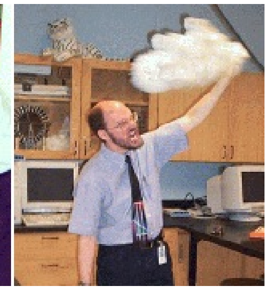
I anticipate that most instructors will have access to a traditional textbook for desired readings, problems, and optional topics. Thus my revised investigations are greatly streamlined, dropping most of the explicit phases of the originals, most of the original readings, and omitting several investigations. I redesigned the laboratories to fit the equipment at my school and to incorporate technologies such as computer-based graphing. I provide alternate versions of some investigations for use with varying equipment (e.g. dynamics carts vs. air tracks). The student handouts often avoid listing specific equipment to allow for greater flexibility from school to school.

The curriculum is organized into 20 units. Each unit begins with a teacher's guide which includes suggested equipment lists, teaching suggestions, and sample answers for the student handouts. Each guide also includes the student handouts for that unit and annotated sample notes for ease of reference.

The disc includes secured Adobe Acrobat PDF versions of the teacher’s guide and, for convenient access, separate unsecured PDF files of the student handouts and sample notes. I have also included editable Microsoft Word files of the student handouts and sample notes, and editable Corel WordPerfect files of the student handouts. Teachers can thus alter the handouts and notes as needed to fit their unique circumstances and preferences, much as I have radically altered the original investigations developed years ago in Norman. All rights are reserved on the copyrighted Teacher’s Guide PDF files to help preserve the security of the answer keys. However, all of other materials are licensed for free use, distribution, and remixing under a Creative Commons Attribution Share-Alike Non-Commercial License.

My Classes at BHS

I have taught physics at Bartlesville High School (BHS) in northeast Oklahoma since 1989. Visit us online at www.bhsok.org

These materials are what I developed for and use in my teaching. These days I usually get through Units 0-17 in my regular classes. Back when there was an AP Physics B curriculum, I held 4th quarter night lectures on the concepts in Units 18-19 and other topics. The curriculum is being revised in 2015 to suit the new AP Physics 1 curriculum.

The curriculum reflects my own idiosyncracies and preferences, including my tendency to solve problems using Fluffy the cat. She is a class mascot whose nine lives were exhausted long ago, and appears in this curriculum in the guise of Phluffy the Physics Feline with her alliterative friends Victor Vector, Velma Velocity, and Phil and Phyllis Physics.

Inquiry Physics at BHS
This course is an in-depth study, centered in lab experience, of the physical world. Central themes are the properties and interrelationships of matter and energy. Topics include: motion in a straight line, graphical analysis of motion, vectors, falling objects, projectile motion, Newton's Laws, friction, circular motion, universal gravitation, work and energy, static electricity, electrical circuits, magnetism, and electromagnetism. Students with poor algebra skills should not attempt this course.

Prerequisites:	One or more units of science Recommend a "B" or better in Algebra I
Grade Levels:	11, 12

Advanced Placement Physics 1 at BHS
Physics 1 AP is a college-level course taken at the high school setting and follows the recommended course outline published by the College Board for the algebra-based test. The course is appropriate for the advanced math/science student who is considering a major in the sciences or engineering. Students will learn to apply math principles to scientific theory. Class topics will include kinematics, dynamics, energy, mechanical waves, sound, and basic electrical circuits.

Prerequisites:	One or more units of science Completion of College Algebra/Trigonometry or Pre-Calculus Pre-AP OR may be concurrently enrolled with instructor approval
Grade Level:	11, 12

Theoretical Basis of the Investigations

The original investigations were constructed to facilitate the learning cycle model originally developed by Dr. Robert Karplus, based upon the mental functioning design of Jean Piaget. It is presumed that through interacting with the phenomenon or concept to be learned, and its associated materials, students *assimilate* the essence of the concept and that assimilation causes them to wonder, or puts the students in *disequilibrium*. The nature of a disequilibrated state leads students to re-equilibrate themselves by *accommodating* their mental structures and thinking processes to the assimilation. In essence, students put their thoughts in accord with those things which give rise to the assimilation. The new thought, according to Piaget's model, now must be *organized* with pre-existing thoughts and ideas, or thought must be put in accord with thought. In this way the students *construct* their own knowledge of the concept being investigated. These new constructs incorporate both the processes of science as well as its content and become part of the students' mental structures rather than just a short-term set of memorized facts about the concept.

The original investigations were explicitly divided into three phases: Exploration, Conceptual Invention or The Idea, and Expansion of the Idea. In the Exploration phase the students gather data which they and the teacher use to arrive at an accommodation which is the concept to be learned. That accommodation begins in the Exploration phase but reaches fruition in the Conceptual Invention or The Idea phase. Organization experiences compose the Expansion of the Idea phase, including readings, problems, and extended laboratories.

The careful reader will be able to discern where the phase boundaries lie in my revised investigations, and is urged to bear in mind that **an overriding principle of this approach to teaching physics is to have the students first collect data and interpret it to develop an idea, rather than first encounter a new concept in lecture or readings**. Equipment and time limitations and students' prior knowledge will lead one to diverge from this approach on occasion, but at the risk of short-circuiting the mental functioning model and having students *learn facts* rather than *do science*.

What is inquiry learning?

Inquiry learning is a dynamic approach that involves exploring the world, asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding. It is stressed in the National Science Education Standards and is a component of the Science section of Oklahoma's Priority Academic Student Skills. But inquiry learning is applicable throughout the curriculum, not just in science education.

Tell me and I forget, show me and I remember, involve me and I understand.

Putting the learner first means changing our educational emphases:

Less emphasis:	**More emphasis:**
Activities that demonstrate and verify subject matter content	Activities that investigate and analyze questions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of content
Management of materials and equipment	Management of ideas and information
Emphasis on individual process skills such as observation or inference	Using multiple process skills – manipulation, cognitive, procedural
Process skills out of context	Process skills in context
Providing answers to questions	Communicating explanations
Investigations confined to one class period	Investigations over extended periods of time
Concluding inquiries with the result of the activity or experiment	Applying the results of activities or experiments to arguments and explanations
Private communication of student ideas and conclusions to the teacher	Public communication of student ideas and work to classmates

Paraphrased from *Changing Emphases to Promote Inquiry* in the National Science Education Standards published in 1996 by the National Research Council; http://www.nap.edu/readingroom/books/nses/html/

What are the levels of inquiry?

There are different levels of inquiry a teacher can utilize in moving students from the traditional inform-verify-practice approach towards freer forms of inquiry.

Confirmation/Verification aka Inform-Verify-Practice	**Structured Inquiry**	**Guided Inquiry**	**Open Inquiry** aka Discovery Learning
Students confirm a principle through a prescribed activity when the results are known in advance	**Students investigate a teacher-presented question through a prescribed procedure** ***(this is the approach used in INQUIRY PHYSICS)***	Students investigate a teacher-presented question using student designed/selected procedures	Students investigate topic-related questions that are student formulated through student designed/selected procedures
Given to the learner: • problem • procedure • solution	**Given to the learner:** **• problem** **• procedure**	Given to the learner: • problem	Given to the learner: • topic

Increasing levels of inquiry require more time, equipment, and teacher flexibility, while providing better student motivation, retention, and learning.

What are the stages in the shift toward inquiry?

One model suggests that teachers go through four stages in various combinations during their teaching careers:

1) **textbook** – using the textbook as the main (and often only) material
2) **activity mania** – students are busy with disconnected and short hands-on activities that usually remain at the level of fun and do not promote true inquiry; beware of grant ideas that are not connected to the curriculum and do not demand much of the learner
3) **imposed inquiries** – the teacher imposes the problem and leads students to the solution
4) **personal inquiries** – students generate and conduct their own investigations

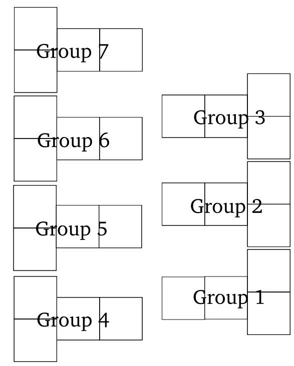
Some information on this page adapted from:

Herron, M.D. (1971). The nature of scientific enquiry. *School Review,* 79(2), 171-212.
See http://edweb.sdsu.edu/wip/four_levels.htm

Moscovici, H. (1998). Shifting from activitymania to inquiry science - what do we (science educators) need to do? In P. Rubba, & J. Rye (Ed.), Proceedings of the 1998 Annual International Conference of the Association for the Education of Teachers in Science (pp. 582-590). Pensacola, FL: AETS. (ERIC No. ED421363). See http://www.ed.psu.edu/CI/Journals/2000AETS/30moscovici.rtf

Lab Groups

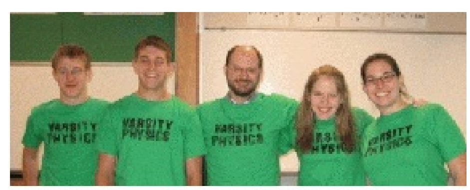
Over the decades my classes have ranged from 12 to 28 students, so I have always run up to seven lab groups in my classes, with each group consisting of three to four students. I like that size of group so that if someone is absent the group can still accomplish the lab, while ensuring that each student can engage with something productive in an activity. Some will try to just be passive observers, so I circulate during a lab to monitor their engagement and, if necessary, draw a student into an activity through questioning or instructions.



I allow students to pick their own seats and in my rooms the lecture area tables have each seated two students, so I arrange every two tables in a T and make them a lab group. Thus the students sit together throughout the class, not merely gathering for lab, since I want their lab work to tie in directly to everything else they do in class. I do not randomly assign students to lab groups for each lab as some teachers like to do, although I do reserve the right to shift students around if needed to improve their focus, and we pick new seats and groups for the second semester to mix things up. I also put a tick mark by each student's name on my seating charts whenever I call on him or her in class. This helps ensure I am giving everyone some attention and no one is escaping my monitoring of their progress.

Some teachers assign students to set roles in a lab or require them to randomize their roles. I tell them to find their own way, but I also circulate during a lab to monitor student engagement and, if necessary, draw a student into activity through questioning or instructions.

Before Lab A in Unit 1 I talk to students about the importance of each student playing a role in each lab so that they will be more focused and successful. The first lab is merely timing a ball going down a ramp. So how can four people each contribute meaningfully?



We discuss how someone can release the ball and someone else time it. Yet another person can be recording the results. But if the group has four members, what about the last person? No, I don't count setting up equipment as an ongoing role, and we don't need a safety officer for our labs. But I tell them they must find a role, so we agree that the last person can be the "Block Holder" who holds the block at the end of the ramp to stop the ball and we joke that, if they can handle it, they can do ball return as well.

Clearly students remember this, as you can see in the photos from when a group surprised me with T-shirts with their roles on the back; one boy was still remembered as the "Block Holder" from their first lab.

As for make-ups, if a student misses a lab they have to make it up individually or with others who were absent. I don't permit them to just copy down data others collected. That means I often get to play a part in the make-up lab, which is good for me as it puts me in their place for awhile so I can empathize with the limitations of our equipment and procedures.

INQUIRY PHYSICS UNITS

Unit 0: Measurement
Unit 1: Motion
Unit 2: Vectors
Unit 3: Falling Bodies
Unit 4: Projectiles
Unit 5: Force and Acceleration
Unit 6: A Property of Matter
Unit 7: The Laws of Motion
Unit 8: Friction
Unit 9: Linear Momentum
Unit 10: Circular Motion
Unit 11: Universal Gravitation
Unit 12: Rotation
Unit 13: Work, Power, and Energy
Unit 14: Electrostatics
Unit 15: Electrical Circuits
Unit 16: Magnetism
Unit 17: Electromagnetism
Unit 18: Optics
Unit 19: Waves