

Chapter 1

Teacher Background Information

1.1. Learning Cycles and Goals for Teaching Physics¹

A physics course should provide students with an understanding of major concepts that prepare them to make more intelligent decisions on societal issues. It should encourage application to common life experiences that make the interpretation of events in the student's environment more meaningful.

Research has shown that most high school students, even those taking physics, have not developed mental structures normally associated with formal reasoning. Consequently the concrete learner needs an introductory experience such that he or she experiences a mental encounter that challenges him or her to do independent reasoning to discover patterns in nature.

Project 2061² states that most of the current modes of instruction “far from helping actually impede the progress toward science literacy. They emphasize learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding, recitation over argument in lieu of doing.”

Based on the constructivist theory of Piaget and expanded by Karplus, Renner, and Arons, to name a few, learning cycles typically have three phases: exploration, concept development (explanation), and concept application (extension).

During the exploration phase, students are encouraged to interact with tangible materials and with one another, so that they have common concrete experiences on which they can build concepts, processes, and skills. To the extent

possible, exploration activities should be concrete and hands-on. As a result of their mental and physical involvement in the activities, students observe relationships, identify variables, and develop tentative explanations for phenomena. During exploration, the teacher's role is that of a mediator or resource agent.

During concept development, the teacher directs and focuses the students' attention to specific aspects of the exploration experiences. The teacher asks students to give their explanations and, through the use of a variety of materials such as texts, multimedia, and verbal discussions, introduces scientific or technological explanations. The concept development phase is teacher or technology directed. This phase continues the process of mental ordering and provides the appropriate vocabulary for the concept.

The primary goal of the application phase is the generalization of concepts, processes, and skills. Ideally, these activities should relate to everyday student experiences. Once students have developed a concept, it is important to involve the students in aspects that verify, extend, and elaborate the concepts, processes, or skills. In some cases, students may still have misconceptions or only understand the concept in terms of the exploratory experience. Application activities provide additional time and experiences to extend the students' conceptual understanding and skills. Through group and cooperative learning, students present and defend their explanations, developing deeper and broader understanding and skills.

1.2. Discussion of Learning Styles and Different Intelligences¹

“Do not train youths to learning by force and harshness, but direct them to it by what amuses their minds so that you may be better able to discover with accuracy the peculiar bent of the genius of each.” —*Plato*

What is smart? Who sets the standards for “smart”? Is it the IQ test or a baseline score on a standardized exam? The ability of a student to memorize and then recite memorized facts is not an indication of understanding. Yet students possessing these attributes are encouraged to enroll in physics courses, and students failing to demonstrate the traditional academic intelligences shy away from such courses because they and others associate success in physics with high achievement in the areas of mathematics and linguistics.

There is a growing body of evidence that shows that students do not learn in the same way. However, teachers often teach all students in the manner in which they themselves prefer to learn. All students can learn—they just learn differently. Many students who are labeled “Learning Disabled” may simply need to be taught in terms of their learning styles. With the call for new methods of science and mathematics instruction and physics first, schools and society need to revise their view of human smartness and encourage instruction based on different learning styles or intelligences. Conceptual physics courses, using the hands-on approach of instruction, allow a larger number of students to succeed in physics.

Howard Gardner, in his book, *Frames of Mind*,³ defines intelligence as:

- ▶ The ability to solve problems one encounters in real life.
- ▶ The ability to generate new problems to solve.
- ▶ The ability to make something or offer a service that is valued within one’s culture.

Learning styles involve the internal structures and processes that affect how a person receives, interprets, and uses information. There are three

strands involved in a learning style:

1. How one receives information
2. How one processes information
3. What environmental preferences one has—examples of environmental preferences are:
 - a. Needs bright light or prefers low light.
 - b. Learns better in the morning or learns better in the afternoon or evening.
 - c. Learns better in groups or learns better alone.
 - d. Prefers to study in quiet surroundings or to study with music or other noise in the background.

Knowing as much as possible about the needs of an individual student will allow the instructor to change the one thing that is most important for learning to that student. It is imperative that students of varied learning styles or intelligences have a smart environment responsive to their own learning styles in which to learn. Also, it is important for opportunities to exist within the classroom for students to interact and work with other students and resources to learn to be problem solvers.

There are many testing instruments that can help the instructor determine the learning styles of his or her students. Many school systems have a testing instrument, and there are people who will come into the classroom, administer the test, and discuss the results with the students. Start with guidance counselors. If they do not have a test themselves, they will know who to contact. The fastest and easiest way to determine the student’s learning preference is to use the testing inventory available within the school. The simple instrument

included in this document evaluates three areas: visual, auditory, and haptic (pronounced so that the “ha” sounds like “a” in avenue). Haptic preference is often called tactile, hands-on learning, or kinesthetic learning. Students can total the points for each learning style, and determine where their strengths and preferences lie.

Whichever instrument is used, learning preferences should be discussed with the students. Explain that no person learns through one style only—everyone is a mixture of preferences or intelligences. Most people appear to excel in one or two of the learning styles or intelligences. It is important to stress that no one way is “good” and another way “bad”; learning styles are simply different. The goal here is for each student to learn in the style that is easiest for him or her, and to contribute to the group information gained using

the particular learning style in which he or she excels.

Following the Learning Channel Preference questionnaire are explanations of the three learning types, primarily for the student, with suggestions for each type of learner. All three of these explanations should be given to each student. These are tips that will make it easier for the student to study and achieve according to his or her learning style.

Additional information for the instructor includes explanations from:

- *C.I.T.E. Learning Styles Inventory*, Piney Mountain Press, 1976.⁴
- Howard Gardner, “The Seven Types of Intelligence” in *Frames of Mind: The Theory of Multiple Intelligences* (BasicBooks, New York City, 1983).

Learning Channel Preference⁵

Problem:

To find out the preferred way in which you learn.

Procedure:

Read each sentence carefully and consider whether it applies to you. On the line, write:

3 often applies 2 sometimes applies 1 never or almost never applies

Preferred Channel: VISUAL

- ___1. I enjoy doodling and even my notes have lots of pictures, arrows, etc., in them.
- ___2. I remember something better if I write it down.
- ___3. When trying to remember a telephone number or something new like that, it helps me to get a picture of it in my head.
- ___4. When taking a test, I can “see” the textbook page and the correct answer on it.
- ___5. Unless I write down directions, I am likely to get lost and arrive late.
- ___6. It helps me to LOOK at a person speaking. It keeps me focused.
- ___7. I can clearly picture things in my head.
- ___8. It’s hard for me to understand what a person is saying when there is background noise.
- ___9. It’s difficult for me to understand a joke when I hear it.
- ___10. It’s easier for me to get work done in a quiet place.

Visual Total _____

Preferred Channel: AUDITORY

- ___1. When reading, I listen to the words in my head or read aloud.
- ___2. To memorize something it helps me to say it over and over to myself.
- ___3. I need to discuss things to understand them.
- ___4. I don’t need to take notes in class.
- ___5. I remember what people have said better than what they were wearing.
- ___6. I like to record things and listen to the tapes.
- ___7. I’d rather hear a lecture on something than have to read it in a textbook.
- ___8. I can easily follow a speaker even though my head is down on the desk or I’m staring out the window.
- ___9. I talk to myself when I’m problem solving or writing.
- ___10. I prefer to have someone tell me how to do something rather than have to read the directions myself.

Auditory Total _____

Preferred Channel: HAPTIC

- ___1. I don’t like to read or listen to directions; I’d rather just start doing.
- ___2. I learn best when shown how to do something and then have the opportunity to do it.
- ___3. I can study better when music is playing.
- ___4. I solve problems more often with trial and error, than with a step-by-step approach.
- ___5. My desk and/or locker looks disorganized.
- ___6. I need frequent breaks while studying.
- ___7. I take notes but never go back and read them.
- ___8. I do not become easily lost, even in strange surroundings.
- ___9. I think better when I have the freedom to move around; studying at a desk is not for me.
- ___10. When I can’t think of a specific word, I’ll use my hands a lot and call something a “what-cha-ma-call-it” or a “thing-a-ma-jig.”

Haptic Total _____



Suggestions for Visual Learners⁵

You will learn better when you read or see the information. Learning from a lecture may not be easy. Try some of these suggestions and create some more that will work for you.

- Write things down because you remember them better that way (quotes, lists, dates, etc.).
- Look at the person while he is talking. It will help you to stay focused.
- It's usually better to work in a quiet place. However, many visual learners do math with music playing in the background.
- Ask a teacher to explain something again when you don't understand a point being made. Simply say, "Would you please repeat that?"
- Most visual learners study better by themselves.
- Take lots of notes. Leave extra space if some details were missed. Borrow a dependable student's or teacher's notes.
- Copy over your notes. Re-writing helps recall.
- Use color to highlight main ideas in your notes, textbooks, handouts, etc.
- Before reading an assignment, set a specific study goal and write it down. Post it in front of you. Example, "From 7:00 to 7:30, I will read the first chapter."
- Preview a chapter before reading by first looking at all the pictures, section headings, etc.
- Select a seat farthest from the door and window and toward the front of the class, if possible.
- Write vocabulary words in color on index cards with short definitions on the back. Look through them frequently, write out the definitions again, and check yourself.



Suggestions for Auditory Learners⁵

You will learn better when information comes through your ears. You need to hear it. Lecture situations will probably work well for you. You may not learn as well just reading from a book. Try some of these suggestions and create some more that will work for you.

- Try studying with a buddy so you can talk out loud and hear the information.
- Recite out loud the thing you want to remember (quotes, lists, dates, etc.)
- Ask your teachers if you can turn in a tape or give an oral report instead of written work.
- Make tape cassettes of classroom lectures or read class notes onto a tape. Summarizing is especially good. Try to listen to the tape three times in preparing for a test.
- Before reading a chapter, look at all the pictures, headings, and talk out loud and tell what you think this chapter will be about.

- Write vocabulary words in color on index cards with short definitions on the back. Review them frequently by reading the words aloud and saying the definitions. Check the back of the cards to see if you were right.
- Before beginning an assignment, set the specific study goal and say it out loud. Example, “First, I will read my history chapter.”
- Read aloud whenever possible. In a quiet library, try “hearing the words in your head” as you read. Your brain needs to hear the words as your eyes read them.
- When doing complicated math problems, use graph paper (or use regular lined paper sideways) to help with alignment. Use color and graphic symbols to highlight main ideas in your notes, textbooks, handouts, etc.



Suggestions for Haptic Learners⁵

You will learn best by doing, moving, or hands-on experience. Getting information from a textbook (visually) or a lecture (auditory) is just not as easy. Try some of these suggestions and create some more that will work for you.

- To memorize, pace or walk around while reciting to yourself or looking at a list or index card.
- When reading a textbook chapter, first look at the pictures, then read the summary or end-of-chapter questions, then look over the section headings and bold-faced words. Get a “feel” for the whole chapter by reading the end selections first, and then work your way to the front of the chapter. This is working whole-to-part.
- If you need to fidget when in class, cross your legs and bounce or jiggle the foot that is off the floor. Experiment with other ways of moving; just be sure you’re not making noise or disturbing others. Try squeezing a tennis or Nerf® ball.
- You may not study best at a desk, so when you’re at home, try studying while lying on your stomach or back. Also try studying with music in the background.
- If you have a stationary bicycle, try reading while pedaling. Some bicycle shops sell reading racks that will attach to the handle bars and hold your book.
- Use a bright piece of construction paper in your favorite color as a desk blotter. This is called color grounding. It will help you focus your attention. Also, try reading through a colored transparency. Experiment with different colors and different ways of using color.
- When studying, take breaks as frequently as you need. Just be sure to get right back to the task. A reasonable schedule is 20-30 minutes of study and 5 minutes of break. (TV watching and telephone talking should not be done during break time!)
- When trying to memorize information, try closing your eyes and writing the information in the air or on a desk or carpet with your finger. Picture the words in your head as you do this. If possible, hear them too. Later, when trying to recall this information, close your eyes and see it with your “mind’s eye” and “hear” it in your head.

1.3. The Learning Cycle Model of a Science Lesson⁶

by Jim and Jane Nelson

The Learning Cycle is a well-known model for science teaching and learning. The original three-phase Learning Cycle was created by physicist Robert Karplus and others in the 1960s⁷ as part of the Science Curriculum Improvement Study (SCIS), a 10-year National Science Foundation project. The FiveE Instructional Model shown in Table 1.1 was adapted by Rodger W. Bybee⁸ from the Karplus Learning Cycle. In this section we present an introduction to the Learning Cycle (see Fig. 1.1) based on the 5E model.

As scientists and science teachers, we often deal with models of physical systems. We understand that each model has strengths and weaknesses, and may change over time. We would like you to think of the following model of a science lesson in the same open way you might think of the Ideal Gas Law. Thus, we present this model realizing that it is neither perfect nor static.

Table 1.1. Components of of the 5E Instructional Model.

Component 1.	ENGAGE—“Wow”
Component 2.	EXPLORE—“Activity”
Component 3.	EXPLAIN—“Link to other concepts”
Component 4.	EXTEND, ELABORATE—“Apply Learning”
Component 5.	EVALUATE—“Feedback”

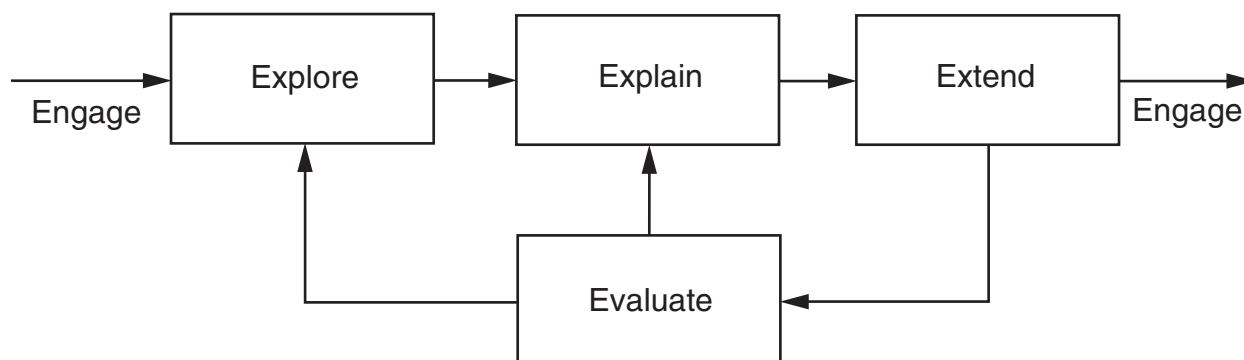


Fig. 1.1. 5E Learning Cycle Model of a science lesson.

NOTE: The activities in this book are based on the three-phase learning cycle not the five-phase discussed in this article. See page 9 to see how the two cycles compare.

The following method for presenting demonstrations and labs is based on the 5E Learning Cycle Model.

1. ENGAGE is the component during which the teacher gets the attention and interest of the students. Often this can be done with a demonstration of a discrepant event. For example, fill a few identical glass bottles with varying amounts of water and label them A, B, C, D, etc. with the amount of water in the bottles increasing.

If you blow across the mouths of the bottles from A to B and so on, the sounds you hear get higher in pitch. If you hit the bottles in the same order, the sounds get lower in pitch. For many, this is counterintuitive and thus a discrepant event. The goal of the demonstration is not to explain; rather it is to engage the students' interest.

2. EXPLORE is the second component and is often a laboratory activity performed by a team of students. For example, measure the depth of the water, find the frequency of the sound waves electronically, and look for a mathematical relationship. The teacher acts as a guide but permits the students to explore and find answers to questions that have been raised. To accomplish this, the teacher often selects among three strategies:

- a. answering the student's question,
- b. pointing the student in a particular direction, or
- c. asking the right question(s) to help the student decide how to proceed.

As young teachers, we delighted in providing the answer. It was years before we realized that this was great for our egos but often clipped the learning wings of our students. Eventually we were able to support our egos just as well by realizing that we were better teachers when we encouraged the students to seek their own answers.

Elsewhere we have listed the defining characteristics of a laboratory activity.⁹

3. EXPLAIN is the component during which the teacher leads the students toward connecting the results of the activity and/or topic with other topics already understood (i.e., making sense of the activity). Here the lecture/discussion format plays a role to take advantage of the teacher's knowledge and experience. This is the time when teachers share their insights with the students by asking probing questions that allow students to move toward personal understanding and scientifically accepted explanations. In the quest for "hands-on" science it is tempting to omit this component, but science lessons must also be "minds-on."

— Here is a delightful 131-year-old quote from DeGraff's *School-Room Guide*:¹⁰

"Definitions should be very sparingly introduced, and never in the first stages of a subject. If given at all, they should sum up knowledge already attained. . . . In every stage of the lessons, with the exception of a few indispensable definitions, the language used by the pupil should be entirely his own, and all set forms of words should be carefully avoided."

The emphasis here is to let the definitions and other concepts arise out of the experience rather than from textbook or lecture. Although everything cannot be learned in this manner, a science lesson is an excellent vehicle for students to gain experience at constructing their own understanding. Such efforts also help students evaluate what they learn from indirect experiences such as reading.

Our interpretation of DeGraff's "set forms of words" is standard or a book definition as opposed to definitions fabricated by the students.

4. EXTEND is the component during which the students find applications of the knowledge gained. During this component students could invent a musical instrument, or try to predict how much water is in a glass container by measuring the frequency of the sound waves the container emits, or derive a mathematical relationship between the variables. We developed the concept of the "Extra" for many of the laboratory activities we do.⁹ The *expectation* is that the students will develop the question and the experimental procedure, and then find the answer. To be sure, we may have to make suggestions to some of them. Students who visit us after graduation often say that this aspect of the course was important and memorable for them.

5. EVALUATE is not only an ongoing component of the lesson, but also an important component during which the student reflects upon the topic at the end of a cycle. As young teachers, we thought of evaluation only as an end-of-unit pencil-and-paper test. It was a long time before we realized that assessment should be ongoing and involve many aspects (e.g., homework assignments, in-class assignments, in-class discussions, model development, written and oral laboratory reports, pencil and paper, poster presentations, projects, public presentations, etc.). We now understand that evaluation involves continuous feedback loops.

In the best scenario, the evaluation component of one cycle will lead to a new topic and a new ENGAGE, hence the phrase "Learning Cycle." See Fig. 1.1.

Clearly, this model is not appropriate for every science lesson, and not every lesson has all five components. Often one or more of the components is missing; nevertheless, this model does give reasonable, realistic, and usually reachable characteristics of a science lesson, and it is a useful model for teachers to consider.

Regardless of the age of the students, the ENGAGE component of the lesson provides motivation. An interesting and engaging start for the lesson helps to keep the students moving forward through the remaining components. In a sense, the ENGAGE component provides the impulse that sets the students in motion.

For students in grades K-5 (and perhaps grades 6-8) it may be appropriate to omit or simplify the EXPLAIN component. This component requires connecting the present lesson's concepts to previous lessons and/or concepts held by the student. However, younger students may not have the experience or the maturity to deal with a thorough EXPLAIN component in an abstract way. Simple, concrete, but **not incorrect** explanations of empirical rules may be enough at an early age.

On the other hand, for graduate students the ENGAGE component of the lesson may be self-imposed as they set themselves on a path of study based on interest and a future goal. For these students the EXPLAIN and EXTEND components become paramount. They have learned a great deal, and connecting and extending concepts is of primary importance.

Although EVALUATION is listed as the final component, it should be blended into all the other components. Thus, it is shown as underlying the entire model in Fig. 1.1. EVALUATION may be thought of as an all-pervasive and constant process.

1.4. Developing a Rubric to Assist in Grading Labs and Other Alternative Assessments

Any method of evaluating student work that does not use traditional multiple choice questions is much easier to grade with the help of rubrics. These include lab reports, graphs, written problems, or any type of alternative assessment. Although lab reports, graphs, and written problems are more difficult to grade, you will have to decide for yourself if the deeper understanding and higher level thinking required of students is sufficient to justify the extra time and effort. If you choose to use alternative assessments, it is important to establish beforehand just how grades are to be determined. Because there may be no right or wrong answer, a scoring rubric is used.

Included are general guidelines for a 3-point rubric and sample rubrics for grading lab reports, graphs, and test or quiz problems. These examples are intended to assist the new physics teacher in developing a rubric for his/her classroom. The final rubric will vary from teacher to teacher and from one type of assignment to another. For more examples of rubrics, search on the Internet or purchase *Science Educator's Guide to Assessment*, by Doran, Chan, and Tamir, published by the NSTA.

General Rubric Guidelines

A grading rubric is generally based on the following:

1. The manner of presentation (quality of graphs, grammar, style, etc.) counts. Nevertheless, it should not be given undue attention. An excellent presentation should not “save” an incorrect or inappropriate response. A poor or sloppy presentation, of course, can make any response unclear and, therefore, incorrect.
2. A response that goes beyond that which was required in the question or assignment should not affect the number of points given—nor should it substitute for an incorrect or inappropriate response. It is strongly advised that students receive a copy of the rubric prior to the assessment so that they know exactly how they will be evaluated.
3. Each teacher will select the appropriate level to be considered “mastery.” It is suggested, however, that the teacher should feel comfortable in saying that at the level selected, the student has adequate understanding (a) on which to build the remainder of physics or (b) to meet the physics proficiency standards of the class, school, or school district.

Table 1.2. General guidelines for 3-point rubric.

Criteria	0 Points	1 Point	2 Points	3 Points	Total
	<ul style="list-style-type: none"> • The response reveals no understanding of the question or task, or no response is attempted. 	<ul style="list-style-type: none"> • Response may reveal some confusion about the question or task. • OR the response is presented in a manner that makes most of it unclear. 	<ul style="list-style-type: none"> • Response reveals general understanding of question or task. • Most components are addressed correctly, but some minor errors or omissions are evident. • The manner of presentation is sufficiently clear that the accuracy or appropriateness of the response can be determined. 	<ul style="list-style-type: none"> • Response reveals thorough understanding of question or task. • Each component of the question or task is correctly addressed. • There is no part of the desired response that is missing. • The response is presented in a coherent manner. 	

Table 1.3. Sample rubric for evaluating a student lab.

Criteria	0 Points	1 Point	2 Points	3 Points	Totals
Problem statement	None or irrelevant	Attempted with limited relevancy	Problem statement identified with basic relevancy	Clearly identified and relevant to the lab	
Experimental procedure and organization of lab report	None or not relevant to the problem statement	General relevance to problem statement, incomplete lab report (missing more than one component, i.e., title, problem, data, conclusion, etc.)	Adequately stated to test problem, missing one lab report component (i.e., title, problem, data, conclusion, etc.)	A thoroughly described step-by-step procedure; all parts of the lab report are complete	
Data and data tables	None; inaccurate data and/or poorly organized table	Data in a table that is incomplete or data not relevant to problem	Relevant data in a labeled table	Accurate data in a labeled and organized table with significant figures	
Analysis of data with graphs, if required	None	Attempted no labels; inappropriately graphed	Uses appropriate data and graphs but incomplete labels or graphs	Clear and concise analysis with regression equations; appropriately labeled graphs	
Questions and answers, if required	None	Attempted response	Response that is incomplete or incorrect according to data	Question is stated and a complete well-written answer is given	
Conclusions	None or inconclusive	Conclusion too general; isn't relevant to problem statement	Conclusion is precise and related to the problem statement with no or vague error analysis	Well-written and insightful conclusion that supports or refutes experimental data or problem statement, including error analysis	
Overall impression	Poor	Inattention to details	Neat with minor grammatical or formatting errors	Neat, concise, complete with no grammatical or formatting errors	

Table 1.4. Rubric for evaluating student graphs.

Criteria	0 Points	1 Point	2 Points	Totals
Variables	The independent and dependent variables are not shown.	The independent and dependent variables are present, but they are improperly placed on the graph.	The independent and dependent variables are placed on the correct axes.	
Labels	The axes are not labeled.	The variable name is shown, but the unit is missing.	The correct variable name and unit are shown on each axis.	
Title	The graph does not have a title.	The graph has a title, but the title is not correctly written.	The title of the graph follows the generic form of "y vs. x."	
Scale	No scale is shown.	The axes are scaled in a non-uniform manner.	The scale for each axis is appropriate for the data.	
Plots	Data points do not accurately represent the information.	Data points are shown, but one or more point(s) is improperly placed.	All data points are clearly and accurately plotted.	
Graph Line	The graph line is not shown on the graph.	The graph line is shown, but is not a best-fit line.	The graph line correctly represents the data with a best-fit line.	

Table 1.5. Rubric for evaluating problem solving.

Criteria	0 Points	1 Point	2 Points	3 Points	Totals
Variables	No attempt	"Givens" are correctly listed.	"Givens" listed and proper symbols are used.	"Givens" listed and proper variable symbols are used; unknown correctly identified.	
Equation	No attempt	Incorrect equation	Correct algebraic expression	Appropriate equation is used.	
Processing	No attempt	Haphazard	All work is shown.	Numerical substitution for variables within equation is shown.	
Answer	No attempt	Incorrect numerical answer	Correct numerical answer or unit (label) but not both.	Correct numerical answer and unit (label)	

1.5. Cooperative Learning¹¹

In your discussion and laboratory sections for this course, your class will be working in cooperative groups to solve written and experimental problems. To help your class learn the material and work together effectively, each group member will be assigned a specific role. Your responsibilities for each role are defined as follows.

Head Physicist

- Receives instructions and clarifications from the teacher.
- Directs the sequence of steps.
- Keeps your group “on track.”
- Makes sure everyone in the group participates.
- Watches the time spent on each step.

Recorder/Reporter

- Acts as a scribe for the group.
- Checks for understanding of all members.
- Makes sure all members of your group agree on plans and actions.
- Makes sure names are on group products.

Materials Manager

- Gathers, maintains, and puts away materials needed for the project.
- Coordinates and assists Chief Engineer.

Chief Engineer

- Assembles project materials under the direction of the Head Physicist.
- Works with the Materials Manager and Recorder/Reporter.
- Makes sure experimental apparatus is correctly set up before starting.

Answers to Some Frequently Asked Questions

Formal cooperative groups need to stay together long enough to be successful. On the other hand, they should be changed often enough so students realize they can make any group successful—that their success is not due to the accident of being in a “magic” group. At the beginning of a new course, groups should be changed every two to three weeks. Later in the course, groups can be changed less often.

Students need to get to know everyone in the class, so the groups should be changed often. By the end of the semester, each student should have worked with almost everyone in his or her class. It helps build a sense of community—everyone works together to help one another learn physics. No matter what career a student enters, he or she will need to work cooperatively with many different kinds of people (not just friends). So he or she should begin to learn how to work successfully in groups.

Key Elements of an Effective Group

Three key elements facilitate an effective group:

- 1. One Group Product:** To promote interdependence, specify that only one report per group can be turned in and all of the group members must sign the report.
- 2. Students can be taught specific roles:** Head Physicist, Recorder/ Reporter, Materials Manager, and Chief Engineer. When there are three students per group, the roles of Materials Manager and Chief Engineer are normally combined. The first time students work together, each member is assigned one of these roles. Each subsequent time the group works together, the roles should rotate. The groups remain together long enough so each group member serves in each role at least once.
- 3. Group Processing:** Set aside time at the end of the first several experiments to have students discuss how well they worked together and what they could do to work together more effectively next time. The “Group Functioning Evaluation” and the “Cognitive Group Evaluation” documents at the end of this section can be used as a guide, along with the two pages at the end of this document.

Hitchhikers

The following techniques have been found to alleviate the “hitchhiker” problem (one student relying on the other group members to do all the work):

1. Assign a role to each student and allow time for group processing (described previously).
2. During some class sessions, individual students can be called on randomly to present their group’s results. This person is not usually the Recorder/Reporter for the group.
3. Assessment includes a group report for which every member receives the same grade. If a student does not participate, that student’s name is not included on the report. Another technique is awarding bonus points to groups when each member meets certain set criteria on an assessment.
4. Another technique is awarding bonus points to groups when each member meets certain set criteria on an assessment.

What Is the Optimal Group Size?

The answer depends on your teaching context. We find that groups of three work a little better than pairs or groups of four. With pairs, there is often not enough background knowledge or skills in the “group.” In groups of four, one member tends to be left out of the process.

How Should Groups of Three Be Formed?

Quite a bit of research has been done on groups of three. The research indicates that mixed gender groups should be made up of two females and one male, not the other way around. Single-gender groups work fine.

One easy method of forming the first set of groups in the fall is to select group members according to each student’s learning style—one visual learner, one auditory learner, and one kinesthetic (haptic) learner (see p. 13). A short discussion about what advantages each type of learner will add to the group makes this grouping more acceptable to the students: visual learners will be able to read and understand the written lab, auditory learners will hear and remember the verbal instructions given by the

instructor, and kinesthetic learners will be good at setting up the equipment and making sure the lab runs smoothly.

Should Students Be Allowed to Form their Own Groups?

It is recommended that students not be allowed to form their own groups until you know your students well enough to be sure that this will not cause problems. It is much easier to prevent difficulties than to fix the problems after they start.

Monitor Groups and Intervene When Necessary

When students work in cooperative groups, they make hidden thinking processes overt, so these processes are subject to observation and commentary. You will be able to observe how students are constructing their understanding of physics concepts.

While groups are working, you should spend time monitoring (observing and listening to group members) to see what they do and do not understand, and what problems they have working together cooperatively. With this knowledge, your interventions can be more efficient. DO NOT get trapped into going from group to group explaining the task or answering questions. If you begin intervening too soon, it is not fair to the last groups you visit. By the time you recognize that all groups may have the same difficulty, the last groups will have wasted considerable time.

1. Monitoring—Establish a circulation pattern around the room. Stop and observe each group to see how easily they are solving the problem and how well they are working together. Don't spend a long time with any one group. Keep well back from the students' line of sight so they don't focus on you.

- a. Make notes about student difficulties with the task and with group functioning so you know what kinds of questions to ask during discussions.
- b. If several groups are having the same difficulty, you may want to stop the whole class and clarify the task or make additional comments that will help them get back on track (e.g., I noticed that you are all Remember to). Another strategy is to stop the class and have one group (or several groups) show the class how they decided to design an experiment or what their results were. You can then spend a few minutes discussing how to design experiments or how to observe and measure.

2. Intervening—From your observations (circulation pattern), decide which group (if any) is obviously struggling and needs attention most urgently. Return to that group, watch for a moment, and then join the group through direct interaction. One way to intervene is to point out the problem and ask the appropriate group member what can be done about it. This establishes your role as one of coach rather than answer-giver. Another way to intervene is to ask them:

- a. What are you doing?
- b. Why are you doing it?
- c. How will that help you? Try to give just enough help to get the group on track, then leave.

One way to coach is to first diagnose the type of problem (e.g., did not manage experiment effectively, came to decision too quickly without considering all the options, can't agree on what procedure to use, etc.). Then ask

1. Who is the Head Physicist?
2. What should you be doing to resolve this problem?

If the student doesn't have any suggestions, then you could suggest several possibilities.

If you observe a group in which one student does not seem to be involved in the discussion and decisions, ask that student to explain what the group is doing and why. This emphasizes the fact that all group members need to be able to explain each step in solving the experimental problem.

If a group asks you a question, try to turn the question back to the group to solve. Again, try to give just enough help to get the group started, then leave. If necessary, lead a class discussion about group functioning.

Discussing Group Functioning Occasionally Is Essential

Students need to hear difficulties other groups are having, discuss different ways to solve these difficulties, and receive feedback from you.

Randomly call on one member from each group to report:

1. one way they interacted well together,
2. one difficulty they encountered working together, or
3. one way they could interact better next time.

Add your own feedback from observing your groups (e.g., "I noticed that many groups are coming to an agreement too quickly, without considering all the possibilities. What might you do in your groups to avoid this?")

Short Bibliography for Cooperative Learning

Circles of Learning (1990), David Johnson, Roger Johnson, and Edythe Holubec. This short book is an excellent introduction/overview to cooperative learning.

Active Learning: Cooperation in the College Classroom (2006), David Johnson, Roger Johnson, and Karl Smith. Cooperation model presented at level of high school and adult students.

The Nuts and Bolts of Cooperative Grouping (2006), David Johnson, Roger Johnson, and Edythe Holubec. Short book with practical suggestions for how to implement cooperative groups in elementary and secondary classrooms.

Structuring Cooperative Learning: Lesson Plans for Teachers (1987), David Johnson, Roger Johnson, and Edythe Holubec. Features original lessons from network of teachers across the United States and Canada. These lessons provide samples for various grade levels and subject areas.

These publications are available from Interaction Book Company, 7208 Cornelia Dr., Edina, MN 55435.

Head Physicist: _____

Recorder: _____

Materials Manager: _____

Chief Engineer: _____

Group Functioning Evaluation

In your group, take a few minutes to discuss and answer these questions about this particular cooperative learning experience. Focus your discussion on the process—what you experienced, felt, and thought about while solving this problem as a cooperative group.

1. What are three ways you did well in functioning as a cooperative group?
2. What problems did you have interacting as a cooperative group?
3. What is one thing that you could do better the next time so that your group will function and interact more effectively?

Cooperative Group Evaluation

Use the following grid to rate yourself on your participation and learning in this exercise. Also, agree on a group rating: 0 = Poor, 1 = Fair, 2 = Good, 3 = Excellent.

Table 1.6. Rate yourself and your group's participation.

Process Elements	Head Physicist	Recorder/Reporter	Materials Manager	Chief Engineer	Group Rating
Preparation for activity					
Participation in activity					
Quality of participation					
Use of roles					
Use of problem-solving strategy					

1. What are three things you did well in functioning as a cooperative group?
2. What is one thing you could do better the next time so your group would function better?
3. What difficulties did you encounter that hindered the functioning of your group and how did you solve them?

Chapter 1 Notes

1. Reprinted with permission from Richard P. Olenick, *Comprehensive Conceptual Curriculum for Physics* (C3P), University of Dallas, Irving, TX, Copyright Richard P. Olenick, 2000.
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3. Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences* (BasicBooks, New York, 1983).
4. Piney Mountain Press Inc., C.I.T.E. Learning Styles, <http://www.pineymountain.com/lscimenu.htm>.
5. Permission to reprint for classroom use. Copyright Lynn O’Brien, Specific Diagnostic Studies, Inc., Rockville, Md.; http://www.as.wvu.edu/phys/rotter/phys201/1_Habits_of_the_Mind/Learning_Styles.html.
6. Adapted from Jim and Jane Nelson, “Learning cycle model of a science lesson,” *Phys. Teach.* **44**, 396–397 (Sept. 2006).
7. R. Karplus and H. Thier, *A New Look at Elementary School Science* (Rand-McNally, Chicago, IL, 1967).
8. R.W. Bybee, *Achieving Scientific Literacy* (Heinemann, Portsmouth, NH, 1997).
9. Jim and Jane Nelson, *Role of the Laboratory in Teaching Introductory Physics* (American Association of Physics Teachers, College Park, MD, 1995).
10. E. DeGraff, *School-Room Guide* (Davis, Bardeen & Co., Syracuse NY, 1878), p. 324.
11. Adapted from the *CPU Project Resource Materials*, Martin Shapiro, Ed. D., 144429 Iroquois Ave., Largo, FL 33774.