# The Levels of Inquiry Model of Science Teaching

(Shaded sections added January 2012; refer to Wenning (2010) for explications of real-world applications component of the Inquiry Spectrum.)

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*The Levels of Inquiry Model of Science Teaching is reviewed and explicated. The Model's levels – discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, and hypothetical inquiry – are integrated with a new 5-stage learning cycle to produce a refined model for science teaching. By systematically addressing levels of inquiry with the use of the associated learning cycle, students develop a wider range of intellectual and scientific process skills. Syntaxes are presented to explain how best to implement learning sequences that promise to lead to a more comprehensive form of scientific literacy. An example of a learning sequence that incorporates the new learning cycle is provided.*

## Models of Science Teaching

Models of teaching provide a basis upon which coherent instructional practices can be based. Instructional models help practitioners understand the importance of and relationships between various activities associated with teaching. Instructional models also provide the framework for interactions between teacher and students. For instance, in a teacher-centered instructional model the focus is placed more on the teacher transmitting information, whereas in a student-centered instructional model the focus is placed more on students constructing knowledge from experiences.

The goal of an instructional model is to help students learn. Any such model should be based upon supportable theories of learning. While more than 20 models of teaching were described by Joyce & Weil (1986), a small subset of these models seem most suitable to science instruction. Among these are constructivist, sociocultural, inquiry, and direct/interactive models. These models stem from ideas proffered by educational theorists such as Dewey, Brunner, Piaget, Vygotsky, and others.

Based upon the works of these theorists, as well as on the efforts of science education researchers, many science teachers and science teacher educators today will agree that there are emerging themes that all science teaching models should incorporate. Hassard and Dias (2005) identified five such themes. According to Hassard & Dias, science instruction should be active, experiential, constructivist, address prior knowledge, and include cooperative and collaborative work. Learning sequences based upon the Levels of Inquiry model of science teaching incorporates these themes, and even more.

## A Levels of Inquiry Redux

Earlier works by Wenning (2005a, 2010) introduced the Levels of Inquiry Model for science teaching and later explicated the associated learning sequences. The author pointed out that by systematically addressing the various Levels of Inquiry – discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, and hypothetical inquiry (collectively known as the inquiry spectrum) – teachers would help students develop a wider range of intellectual and scientific process skills. Now included in the inquiry spectrum is real-world applications with its two variants – solving end-of-chapter textbook problems and solving authentic problems. When the general inquiry spectrum is translated into day-to-day classroom lessons, a learning sequence results.

To more fully appreciate what the inquiry spectrum does for both teacher and students, it is imperative to examine the primary pedagogical purposes of each of the levels of scientific inquiry. They are outlined in Table 1.

| Level of Inquiry | Primary Pedagogical Purpose |
|---|---|
| Discovery Learning | Students develop concepts on the basis of first-hand experiences (a focus on active engagement to construct knowledge). |
| Interactive Demonstration | Students are engaged in explanation and prediction-making that allows teacher to elicit, identify, confront, and resolve alternative conceptions (addressing prior knowledge). |
| Inquiry Lesson | Students identify scientific principles and/or relationships (cooperative work used to construct more detailed knowledge). |
| Inquiry Laboratory | Students establish empirical laws based on measurement of variables (collaborative work used to construct more detailed knowledge). |
| Real-world Applications | Students solve problems related to authentic situations while working individually or in cooperative and collaborative groups using problem-based & project-based approaches. |
| Hypothetical Inquiry | Students generate explanations for observed phenomena (experience a more realistic form of science). |

Table 1. *Focus of each of the model's six levels of inquiry. This table is suggestive, not definitive.*

The Levels of Inquiry Model of Science Teaching is based in part on John Dewey's turn-of-the-twentieth-century call for experiential learning. Dewey's call for the use of experiential learning and inquiry practice was directed toward enhancing the general scientific literacy of school children. He argued that teaching theory should be more closely associated with desired outcomes (1904), and that the best way to get students to become more scientifically aware and informed is through the processes of experiential learning – having students learn science by mimicking the work of scientists. Six years later, Dewey (1910, p. 25) noted, "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter." Dewey envisioned learning driven by a series of rudimentary learning cycles (modern parlance) in which students would receive an impulse, make an observation, derive a conclusion from that observation, and make a judgment as to its worth. The students would then complete another such cycle of learning triggered by a new impulse. By completing a series of such cycles, students would build up knowledge on the basis of experience. (See Figure 1.)

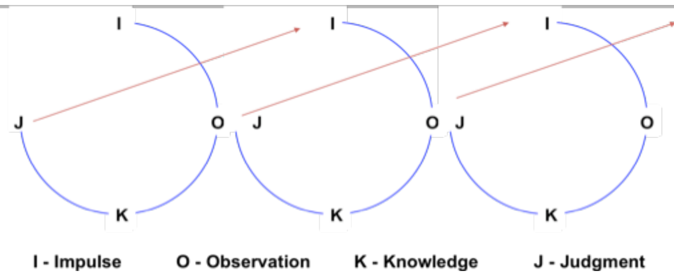


Figure 1. *John Dewey's 1904 Model of Experiential Learning*

While Dewey's was a thought-provoking idea, it was never widely adopted. From a modern perspective, the problem with Dewey's model of experiential learning is that it is essentially "horizontal." While it does utilize a very rudimentary form of learning cycle, the model did not directly call for development of progressively more sophisticated scientific and intellectual process skills that we want to inculcate among students today in this vastly more advanced technological age. The Levels of Inquiry Model of Science Teaching takes these factors into account and uses a more sophisticated form of learning cycle that more closely mirrors the work of professional scientists. This newer 5-phase learning cycle and its relationship to the inquiry spectrum is shown in Figure 2.

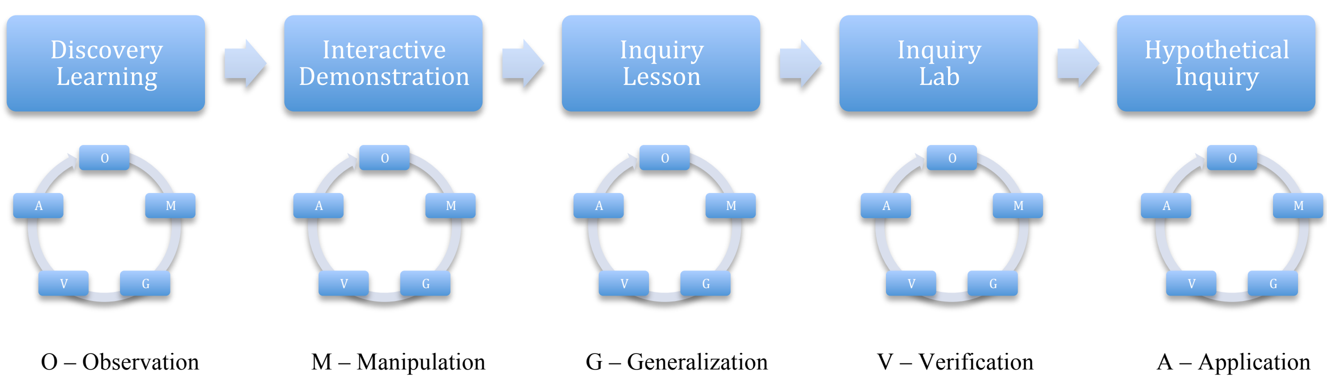


Figure 2. *Levels of Inquiry Model of Science Teaching*

**The Inquiry Spectrum's Relationship to Learning Cycles**

Many different learning cycles have been proffered since Robert Karplus introduced his learning cycle in 1962. The number of learning cycles has proliferated substantially since that time, each with its own emphasis and viewpoint on teaching. Table 2 gives a number of learning cycles that have been applied to science teaching more recently.

Learning cycles are essential elements of science instruction because they help teachers sequence learning activities. They can provide structure for lesson planning and delivery. By using learning cycles as guides, teachers can more easily plan instruction that mimics the way that scientists tend to work. By integrating a learning cycle into each components of the inquiry spectrum, students can gain a much more comprehensive understanding of all the intellectual and scientific process skills that are inherent in each of the levels of inquiry. Indeed, the Levels of Inquiry Model of Science Teaching is a series of learning cycles operating within the context of a larger cycle that encompasses different levels of inquiry. The over arching levels of inquiry cycle will be initiated each time new subject matter is introduced.

The various levels of inquiry – discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, and hypothetical inquiry – are more fully explicated with the use of a learning cycle. A new 5-stage learning cycle introduced with this article provides additional structure to each level of the inquiry spectrum. By moving through the various stages of a learning cycle and levels of the inquiry spectrum, a student more fully comprehends science as both process and product, and gains a much deeper understanding of the scientific enterprise. *This new 5-stage learning cycle constitutes the basic syntax for each level in the Levels of Inquiry Model of Science Teaching.*

| 3-Stage Karplus | 4-Stage Art of Teaching Science | 4-Stage Dykstra | 5-Stage Bybee | 7-Stage Eisenkraft | 5-Stage Levels of Inquiry |
|---|---|---|---|---|---|
| Exploration | Invitation | Elicitation | Engage | Elicit | Observation |
| Invention | Exploration | Comparison | Explore | Engage | Manipulation |
| Discovery | Explanation | Resolution | Explain | Explore | Generalization |
| | Taking Action | Application | Elaborate | Explain | Verification |
| | | | Evaluate | Elaborate | Application |
| | | | | Evaluate | |
| | | | | Extend | |

Table 2. *Learning cycles applied in science teaching; modified from Gallagher (2006)*

### The 5-Stage Levels of Inquiry Learning Cycle

The new 5-stage Levels of Inquiry learning cycle originated from some 15 years of teaching experience within the Illinois State University physics teacher education program. While not substantially different from any of the learning cycles identified in Table 2, this 5-stage learning cycle places a consistent and stronger emphasis on the action of students rather than on the actions of the teacher, and – in the author's opinion – perhaps more simply and more closely mimics the overall processes of rudimentary physical science. The five stages of the Levels of Inquiry learning cycle are as follows:

- *Observation* – Students observe a phenomenon that engages their interest and elicits their response. Students describe in detail what they are seeing. They talk about analogies and other examples of the phenomenon. A leading question is established that is worthy of investigating.
- *Manipulation* – Students suggest and debate ideas that might be investigated and develop approaches that might be used to study the phenomenon. They make plans for collecting qualitative and quantitative data and then execute those plans.
- *Generalization* – Students construct new principles or laws for phenomena as needed. Students provide a plausible explanation of the phenomenon.
- *Verification* – Students make predictions and conduct testing using the general law derived from the previous stage.
- *Application* – Students set forth their independently derived and agreed-upon conclusions. The conclusions are then applied to additional situations as warranted.

Throughout this 5-stage process, students continuously communicate ideas, approaches, processes, data, and results – including difficulties and tribulations. They share in successes and redress failures. They operate as members of both small and whole group communities to develop, confirm, and apply findings derived at each level of inquiry.

### General Syntaxes of the Various Levels of Inquiry

While the 5-stage learning cycle constitutes the basic syntax of teaching within the inquiry spectrum, it is very broad and subject to modification when utilized. Several examples are now provided that represent (if not with perfect precision) how learning cycles are implemented within the Levels of Inquiry Model. In the strictest sense of the term "syntax", there are no specific steps that must always be followed. In a more pragmatic sense, general syntaxes will flow from but not slavishly adhere to the 5-stage learning cycle.

The reader should keep in mind that teaching is more of an art form than a science. There is no established set of rules that educators can point to and say, "Do this; it will work every time." The educational process is complex and there are as many ways of teaching as there are teachers. Nonetheless, the Levels of Inquiry Model of Science Teaching suggests certain general practices and approaches that are described here as syntaxes.

As students move from guided to bounded to free inquiry labs and then on to hypothetical inquiry, the locus of control shifts from the teacher to the students. As students – perhaps working individually – move through the forms of hypothetical inquiry, their work becomes intensely individualistic and even private. As a result, syntactic steps are not presented for either more advanced labs and hypothetical inquiry because it is now primarily up to students to design and conduct their own lab activities and provide and work out their own hypothetical explanations. These processes necessarily will be idiosyncratic in nature and cannot therefore be supplied.

How subject matter is introduced to students will depend strongly on the nature of that subject matter. In some subject matter various aspects of the 5-stage learning cycle will be emphasized and others deemphasized, or perhaps skipped altogether. For instance, helping students to discover concepts related to motion (a very concrete activity) will likely be considerably different from learning about the concepts related to relativity (a much more abstract form of student learning). Nonetheless, it is still possible to provide useful generalities.

### Discovery Learning

Discovery learning entails developing conceptual understanding on the basis of experience. Descriptions of the phenomenon (answers to "what" and "how" questions) are elicited. Explanations of the phenomenon (answers to "why" questions) are not elicited. However, if unsolicited explanations do arise, they should be set aside for future investigation. The following general steps can be used to develop concepts at this level of the inquiry spectrum:

1. The teacher introduces students to one or more interesting physical examples of a phenomenon to be studied. Students are attracted to and intrigued by the display of the phenomenon.
2. The teacher asks students to describe (not explain) what they are seeing, and to relate commonalities they are seeing between the various examples.
3. The teacher encourages students to identify, and describe other analogous physical situations where the phenomenon also might be observed.
4. The teacher encourages students, now working in small groups, to interact with various examples of the phenomenon, encouraging them to change variables and see what the effect is on the phenomenon.
5. The teacher asks students to discuss ideas, identify relationships, draw conclusions, and develop insights as to what is happening – what accounts for the phenomenon being observed.
6. As appropriate, the teacher provides names for the concepts so developed.

### Interactive Demonstration

Sokoloff & Thornton (2004) provide an 8-step approach for conducting interactive lecture demonstrations, the first seven of which are generally consistent with the interactive demonstration component of the inquiry spectrum as well as the model's 5-stage learning cycle. Paraphrasing their first seven steps and replacing their eighth, provides the following general syntax for the inquiry spectrum's interactive demonstrations:

1. The teacher introduces a demonstration describing the mechanical process that will be followed to exhibit the desired phenomenon. This is done entirely without explanation or a statement of outcome.
2. The teacher asks students to think about what will happen and why it will happen when the demonstration takes place, and to state their individual predictions and explanations in writing.
3. The students are engaged in small group discussions with their one or two nearest neighbors, the purpose of which is to share their predictions and explanations in the hope that they will self correct in the light of alternative predications and explanations.
4. The teacher elicits from the students a common prediction and explanation using a consensus-building process.
5. The students record, each on their own record sheet, the group's final prediction and explanation.
6. The teacher carries out the demonstration in an obvious fashion with results being clearly evident. The demonstration is repeated as necessary until the outcome is clear.
7. The teacher asks the students to compare the results of the demonstration with both sets of predictions. The teacher identifies any alternative conceptions that have been elicited.
8. If authentic alternative conceptions are identified (as opposed merely to student learning difficulties), the teacher confronts and resolves the alternative conceptions, and reinforces new learning using the Elicit-Confront-Identify-Resolve-Reinforce (ECIRR) approach for dealing more effectively with alternative conceptions (Wenning, 2008).

### Inquiry Lesson

The inquiry lesson employs a think-aloud protocol in which the teacher encourages students to act like scientists in a more formal experimental setting where efforts are now taken to define a system, and both control and manipulate a single independent variable to see its effect on the single dependent variable. The following general procedures should be used:

1. The teacher identifies the phenomenon to be studied, including the goal of the investigation. The teacher clearly enunciates the guiding question for the investigation to follow.
2. The teacher encourages students to identify the system to be studied, including all pertinent variables. Students are asked to distinguish between pertinent and extraneous variables.
3. The teacher encourages students to identify those independent variables that might have an effect on the dependent variable.
4. The teacher asks students to devise and explain a series of controlled experiments to determine qualitatively any effects of the independent variables on the dependent variable. The teacher uses a think-aloud protocol to

 

explain what is happening experimentally and why it is being done in the fashion demonstrated.
5. The students, under the watchful eye of the teacher, conducted a series of controlled experiments to determine qualitatively if any of the independent variables has an affect on the dependent variable under controlled conditions.
6. The students, with the assistance of the teacher, state simple principles that describe all relationships observed between the input and output variables.
7. The teacher, with the aid of the students, clearly identifies those independent variables that need to be further studied in relation to the dependent variable in a follow-up inquiry lab that will be used to identify more precise relationships between variables.

Inquiry Labs, Real-world Applications, and Hypothetical Inquiry

Because students become more and more knowledgeable about the processes of science as they repeatedly progress through the inquiry spectrum employing the associated 5-stage learning cycle, they become more and more independent in both thought and action despite the fact that the intellectual sophistication of the tasks before them increases with each level. Because this is so, it is less incumbent upon the teacher to provide students with a script for action. While this might be necessary to so during the early part of a course, it becomes much less necessary – and perhaps an anathema as students see it – as the school year progresses. As a result, the locus of control shifts from the teacher to the students and the need for a general syntax – even the advisability of such syntax – becomes questionable. Nonetheless, the teacher should still proctor student work and be prepared to respond to questions when the students are confounded. Students should be reminded to follow in general the five-stage learning cycle associated with the Levels of Inquiry Model that tends to be characteristic of the work of scientists. Teachers generally should avoid directly answering student questions; rather, they should gently coax them to answer their own questions with the use of leading questions, and provide hints as necessary.

## Learning sequence example from optics

An example is now provided showing how levels and inquiry and learning cycles can be integrated to produce a learning sequence dealing with lenses. The general idea for the lesson was derived from the Modeling Method of Instruction, and assumes that students understand shadow formation and that light propagates in straight lines. The main goal of the learning sequence is to have students construct an understanding of how a refracting telescope works.

Discovery Learning (using lenses as hand magnifiers)

- *Observation* – Students are given two convex lenses, one thick compared to the edge (short focal length) and one thin compared to the edge (long focal length). At the teacher's direction, students describe the differences in shape and any other things they can determine about the lenses – what they do, how they perform and so on. Students write their findings on whiteboards that include such things as ability to provide erect and inverted images
- *Manipulation* – Students are asked to determine if there is any relationship between the "thickness" of the lenses and the size of images (magnification) they view through them if held the same distance from a printed page. Or, they might be asked to determine the relationship between the distance of an object from the lens and the lens' ability to product erect or inverted images.
- *Generalization* – Students generate one or more rules for convex lenses such as, "Thick lenses produce larger images than do thin lenses when held at the same distance from a piece of newsprint." or "There is a specific distance for each lens where the image shifts from erect to inverted. The distance appears to be related to the thickness of each lens."
- *Verification* – Because scientific conclusions are the purview of the scientific community and not the individual or even a small group within the community, these findings are again shared with the whole group so that the conclusions can be checked and verified.
- *Application* – Once the community of learners has verified the findings of individuals and groups, students apply what they have learned to new situations. For example, students complete a worksheet or answer a series of "what if" questions from the teacher that apply the knowledge to specific situations.

Interactive Demonstration (using a lens to project)

- *Observation* – Students observe as the teacher uses a large convex lens to project an image of a bright outdoor scene onto a screen within the darkened classroom. With the instructor's use of leading questions, the students note such things as the focal distance and that the image is inverted and in color.
- *Manipulation* – The teacher, referring to this set up, suggest a number of experiments to determine what controllable factors influence the production of the image. For example, the teacher suggests the change in lens thickness (using another lens) to see how it affects the focal distance. Students make predictions and then the demonstration is carried out. They might suggest changing the effective size of the lens by masking its edge to see what effects diameter have on the image production. Again, students make predictions before the demonstration is carried out. The teach might ask what would happen if a hand – held far from the lens and the very close to the lens – was used to cast shadows on the lens to see effect on the image produced. The students again predict and their forecasts checked with another set of demonstrations.

 

- *Generalization* – Based on their experiences with the demonstrations, students draw conclusions and document their findings in writing.
- *Verification* – Students then receive two index cards from the teacher – one with a pinhole in the center and the other without a pinhole. They are asked to hold the index card with the pinhole nearer the window and place the second index card in the shadow of the first. They can then study the new image and compare with the results from the lensed projection.
- *Application* – The teacher asks the students to determine whether or not a pinhole acts like a convex lens and visa versa. If so, to what extent? How are pinholes and convex lenses different?

Inquiry Lesson (understanding image projection)

- *Observation* – Students watch as the teacher explains how to use a pinhole projector to produce the image of a light bulb on a screen. (A small box with a pinhole in one end and a cut out with a wax paper screen on the other does well. The box is cut in half allowing the two sections to slide in and out of one another allowing the distance between the pinhole and screen vary.)
- *Manipulation* – During this phase, students are asked to describe which pertinent and controllable factors might influence the shape, size, orientation, and overall appearance of the projected image. Only one of the many possibilities are actually implemented during this phase without making precise measurements, reserving the other possibilities for study during a follow-up laboratory activity.
- *Generalization* – Modeling scientific inquiry, students are asked to generalize the findings from the prior phase using appropriate terminology.
- *Verification* – The students are now given pinhole projectors and light bulbs of their own and asked to verify individually or in small groups the single finding of the whole group.
- *Application* – The students are informed that they will now use variations of the approach just used to conduct a qualitative study of the other components of the pinhole camera system.

Guided Inquiry Lab (finding qualitative relationships among variables using controlled experiments)

- *Observation* – The teacher, reviewing the inquiry lesson, asks students to conduct controlled experiments with the pinhole projector and light source such that there is only one independent variable and one dependent variable. The teacher gets students to define pertinent variables such as $d_o$ (distance of the objective from the pinhole), $d_i$ (distance of the image from the pinhole), $h_o$ (height of the light bulb filament), and $h_i$ (height of the filament image) prior to beginning the next phase.
- *Manipulation* – Students, conducting controlled qualitative experiments (no measuring instruments permitted), change one variable at a time while holding two constant and allowing the fourth the vary to see the consequences of changes in the first.
- *Generalization* – Students, making a series of observations while changing the independent variable over a wide range, write their findings in words (no mathematic equations) on a whiteboard or other surface that can readily be shared with the entire group.
- *Verification* – By communicating results, students find that other study groups have drawn the same conclusions from evidence. If there are any conflicts additional data are collected until such time as it is clear that nature does act uniformly and that differences that arise are likely the result of human error. This helps students to understand the nature of science (Wenning, 2006).
- *Application* – The students complete a worksheet that includes multiple examples of ray tracings that explain why the image is fuzzier when using a large pinhole, why images are inverted in relation to the object, why the image is larger if the screen is made more distant from the pinhole and visa versa, why the image gets smaller for a fixed pinhole-screen distance if the distance between the lamp and the pinhole gets smaller and visa verse, how changing the orientation or size of the light bulb affects the image, why multiple pinholes produce multiple images and so on.

Bounded Inquiry Lab (finding relationships among quantifiable variables using controlled experiments)

- *Observation* – In a follow-up discussion, students discover that other students observed the same basic relationships (e.g., as $d_i$ increases, $h_i$ increases under the condition of fixed system parameters).
- *Manipulation* – The teacher jigsaws the larger problem into smaller components (e.g. two groups conduct a controlled study of the relationship between $d_i$ and $h_i$, another two groups study the relationship between $d_o$ and $h_i$, etc.)
- *Generalization* – Students collect pertinent data and generate mathematical relationships using graphical analysis.
- *Verification* – Students share their mathematical findings (e.g., $d_i \propto h_i$, $d_i \propto 1/h_o$, do $\propto h_i$, and $d_o \propto 1/h_o$) with other groups, and confirm findings as appropriate.
- *Application* – Students combine the small group findings to produce a general relationship between quantifiable variables (e.g., $h_i/h_o = d_i/d_o$). Students are encouraged to find a definition of magnification, M. They should easily be able to produce the following relationship: $M = h_i/h_o$.

(continued next page)

 

Real-world Applications (developing a working definition of magnification)

- *Observation* – Students are provided with an optical bench and a set of three of lenses consisting of one long, one intermediate, and one short focal length lens. They are then asked to “invent” a telescope that produces a maximum magnification of a distant object.
- *Manipulation* – Students – already knowing what a telescope looks like – switch out various lenses to serve as objective and eyepiece. They conclude that the maximum magnification is achieved when the longest focal length lens is used as an objective and the shortest focal length lens is used as an eyepiece.
- *Generalization* – Students enunciate a rule to the effect that magnification, $M$, is proportional to the focal length of the objective, $F$, and inversely proportional to the focal length of the eyepiece, $f$.
- *Verification* – Students exchange various combinations of lenses for objective and eyepiece and verify if the rule they have proposed, $M \propto F/f$, is likely to be correct.
- *Application* – Students determine the focal lengths of all lenses by projecting images of very distant objects onto a sheet of paper and measuring the distance between the lens and the paper. From these data, they calculate the magnifications of various combinations of lenses.

Applied Hypothetical Inquiry (explain how a refracting telescope works)

- *Observation* – Students observe as the teacher uses two lenses in combination to produce images as with a refracting telescope. Student attention is drawn to the fact that the image is inverted despite the fact that light from the object pass through two lenses.
- *Manipulation* – Students are given one long and one short focal length convex lens and told to “invent” their own telescope.
- *Generalization* – Students attempt to explain the role of the lenses to both project a real image (using the long focal length objective lens) and to examine that image with the use of a short focal length hand magnifier (eyepiece).
- *Verification* – Students verify that a real image is indeed produced between the objective and the eyepiece by inserting an index card in the focal plane of the objective lens.
- *Application* – Students use their knowledge of how a refracting lenses work to provide an explanation of how a refracting telescope works something to the effect that, “An objective lens produces a real image on a plane and an eyepiece is used beyond that focal plane to both to view and magnify the resulting image.”

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Pure Hypothetical Inquiry (accounting for the nature of the magnification relationship)

- *Observation* – Students look through a telescope set up on an optical bench that consists only of an objective lens and an eyepiece lens. The telescope is focused on a very distant object. The teacher introduces a sheet of paper into the focal plan of the objective where the students clearly see that a real image is formed.
- *Manipulation* – Students are informed of the focal lengths of both lenses and ask to determine the relationship between these focal lengths and the separation between the lenses when a very distant object is clearly focused. They conclude that the separation is $F + f$, the sum of the focal lengths of the objective and eyepiece lenses.
- *Generalization* – Students draw a ray diagram for the distant object, objective lens, eyepiece, and eye. Between the objective and the eyepiece, they denote the position of the objective’s image plan and draw an inverted real image produced by the objective such as an arrow. From this construct and by comparing the true angular size of the object with the apparent size of the object as seen through the eyepiece, students determine that the magnification of the system is simply a ratio of the focal lengths of the objective and eyepiece, $F/f$.
- *Verification* – Students can confirm the above relationship by comparing it with outcomes from the pinhole projection activity in which $M = h_i/h_o = d_i/d_o$
- *Application* – Students compare the results of magnification from the formula, $M = F/f$, and the ratio of true and apparent angular sizes of the object.

## Implementing the Levels of Inquiry Model

Creating effective learning sequences can be a daunting and time consuming task, as the author’s experiences have shown. Perhaps that is because many of us as teachers don’t have many experiences explicitly developing detailed, progressive, and increasingly sophisticated lessons for our students. If learning sequences based on the Levels of Inquiry Model of Science Teaching are to be generated, perhaps they should be the effort of work groups such as used with the lesson study process (Stigler & Hiebert, 1999). This approach has been used with considerable success in the Physics Teacher Education program at Illinois State University (Wenning & Khan, 2011).

Clearly, the time required to prepare and teach a learning sequence using the Levels of Inquiry Model of Science Teaching is considerable. This is only one of the many reasons that some science teachers fail to include inquiry practices in their instruction (Costenson & Lawson, 1986). Other reasons include time and energy, too slow, reading too difficult, risk too high, tracking, student immaturity, teaching habits, sequential text, discomfort, too expensive, and lack of teaching materials suitable for hands-on learning. These problems, either perceived or real, and how to address them have been dealt with earlier by

 

Wenning (2005b). In-service teachers should be aware of the fact that as students move repeatedly through the various levels of inquiry and the associated learning cycles, the whole process of developing these kinds of learning activities becomes second nature to the teacher.

There are additional sources of resistance to inquiry that comes from sources such as peer teachers, school administrators, parents, and even the students themselves. The author has addressed how teachers can effectively deal with these types of resistance through the processes of climate change (Wenning, 2005c).

Granted, no teacher who is concerned with breadth of coverage as well as depth of instruction will want to use learning sequences exclusively. That is acceptable and understandable. However, to use more didactic approaches (e.g., direct instruction) to the near exclusion of inquiry-oriented teaching is troubling, as teaching by telling is known not to be terribly effective for developing long-term understanding. Equation-based teaching often leaves students with precious little conceptual understanding that can be readily applied to real world experiences.

Levels of inquiry, the inquiry spectrum, learning sequences, and classification of their associated skills will continue to be refined as more learning sequences are developed. Such is the development of an educational model.

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