

Levels of Inquiry Model of Science Teaching: Learning sequences to lesson plans

Carl J. Wenning, Ed.D., Department of Physics, Illinois State University, Normal, IL, USA, Email: wenning@phy.ilstu.edu and Manzoor Ali Khan, Senior Lecturer, Aga Khan Higher Secondary School, Konodass, Gilgit-Baltistan, Pakistan, Email: chaman_humar@yahoo.com

This article presents a framework for lesson planning using the Levels of Inquiry Model of Science Teaching. The model's inquiry spectrum consists of discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, and hypothetical inquiry. Each level of this inquiry spectrum is associated with a 5-stage learning cycle consisting of observation, manipulation, generalization, verification and application. This article provides several examples of learning sequences showing how to plan lessons for each level of inquiry. The article has implications for classroom teachers, teacher educators and researchers who are directly involved in the teaching and learning process dealing with the construction of pedagogical content knowledge in the areas of introductory physics.

The Levels of Inquiry Model of Science Teaching (Wenning, 2005, 2010, and 2011) is an approach to instruction that systematically promotes the development of intellectual and scientific process skills by addressing inquiry in a systematic and comprehensive fashion. When taught using the Levels of Inquiry approach, students have the opportunity to make observations, formulate predictions, collect and analyze data, develop scientific principles, synthesize laws, and make and test hypotheses to generate explanations. The leading author's various articles dealing with Levels of Inquiry provide a framework for inquiry-oriented instruction by way of its inquiry spectrum. No longer is inquiry-oriented teaching to be seen as an amalgam of convoluted and disconnected processes. Rather, it is to be treated systematically as a series of hierarchical approaches each with affiliated process skills.

Wenning (2005) presented a hierarchy of inquiry-oriented teaching approaches that included the following levels: discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, and hypothetical inquiry. Discovery learning helps students develop concepts on the basis of teacher-directed experiences. Interactive demonstrations help teachers elicit, identify, confront, and resolve alternative conceptions. Inquiry lessons guide students to identify scientific principles and/or relationships. Inquiry labs allow students to establish empirical laws based on measurement of variables. Hypothetical inquiry permits students to derive explanations for observed phenomena. The inquiry spectrum constitutes a progressive level of intellectual sophistication and changing locus of control that shifts from the teacher to the student.

Wenning (2010) associated the inquiry spectrum with learning sequences for the first time. Learning sequences are specific cases of the application of the inquiry spectrum. Learning sequences help to ensure that students develop a wider range of intellectual process skills than are promoted in a typical introductory physics course that uses more limited modes of instruction. Wenning notes that it is imperative for teacher educators, teacher candidates, and in-service teachers to have a thorough

understanding of the full spectrum of inquiry-oriented approaches to teaching so that they can more easily help teacher candidates and students achieve a higher degree of scientific literacy. To give a more practical understanding of the inquiry spectrum framework and associated learning sequences, contextualized examples were provided.

Wenning (2011) provided more information about the Levels of Inquiry Model of Science Teaching by associating the inquiry spectrum with a new 5-stage learning cycle that incorporates observation, manipulation, generalization, verification, and application. Each of these stages focuses attention on student activities and provides a more practical example of the nature of typical scientific approaches in the study of the world.

The present authors now provide a number of sample learning sequences that address a wide range of topics generally addressed in an introductory physics course. The purpose of these learning sequences is to give the reader a clearer understanding of inquiry approaches and present a framework for how to develop day-to-day classroom lesson plans.

The following examples (see Appendix) do not adhere slavishly to the 5-stage learning cycle of Levels of Inquiry Model of Science Teaching. Such details constitute the fine structure of lesson planning and are left to the reader who might use these learning sequences to teach science content and process.

Sometimes there are options for conducting one or more level of inquiry activities within a learning sequence. These are indicated by the presence of thin horizontal lines splitting various boxes in the table. Either or both approaches can be used depending upon time, material, and interest of the students.

Several references are made in the following appendix to the Illinois State University Physics Department's *Student Laboratory Handbook*. This online resource consists of 25 one- to three-page articles written by Wenning between 2004 and 2011 and refined over time. The *SLH*, as it is known locally, is used to provide background readings for

students enrolled in introductory physics courses, and serves as reference material in the department's Physics Teacher Education program (<http://www.phy.ilstu.edu/pte/>). Resources within the *SLH* deal with graphical analysis, mathematical methods, experimental procedures, and laboratory equipment. It is freely available online at the following URL: <http://www.phy.ilstu.edu/slh/>.

Learning Sequences to Lesson Plans

Table 1 shows a learning sequence dealing with pinhole projection and image formation. A series of lessons explicating the use of the learning cycle and based in part on this learning sequence was presented earlier in Wenning (2011) Additional comments are provided here for the development of lesson plans in general.

Teachers should be cognizant of the fact that the lesson sequence frameworks should be integrated with the 5-stage Levels of Inquiry Model of Science Teaching learning cycle to produce the associated lesson plans.

As a lesson plan is developed for a single class period, all teachers needs to be aware of the fact that sometimes one,

two, three, or even more of the levels of inquiry can be addressed in the same lesson. Some of the concepts addressed in the various levels of inquiry don't take that long to address. Discovery learning and interactive demonstrations in many cases won't take longer than about 10-15 minutes each.

Every in-service teacher will likely have his or her framework for writing a lesson plan. This generally is not the case for teacher candidates. In the Illinois State University physics teacher education program teacher candidate develop idealized (read "lengthy") lesson plans that include a larger number of elements than is typical for in-service teachers. (The distinction between "idealized" and "pragmatic" is made clear to the students and helps alleviate some of the stress associated with future teaching.) This extended framework helps teacher candidates understand the critical components that should be part of every lesson plan, but that are often not explicitly stated in pragmatic lesson plans used by in-service teachers. Items A through L below constitute the framework for the ISU idealized lesson plan. It explains each of the elements that teacher candidates must include in their idealized lesson plans.

Pinhole Projection	<p>Discovery Learning: Students are introduced to the concept of pinhole projection with the use of two index cards and a clear light bulb with a large filament. The first index card with the pinhole is held closer to lamp; the second index card is held in the shadow of the first. Students see image produced on second index card. They discover inversion, distinction between image and object, and note that distance of the object (d_o) and distance of the image (d_i) (both measured from the pinhole) have an effect on image height (h_i). The object height (h_o) is fixed. Students image brightly lit objects outside the classroom window or overhead lamps in similar fashion. Students note both inversion of image and color.</p>	<p>Interactive Demonstration: The instructor explains to students the use of a pinhole camera – two boxes sliding in and out of one another with a pinhole in one end (aluminum foil) and a projection screen (white vellum or wax paper) on the other. Students are asked to predict what would happen to h_i if d_i and d_o were varied. Students are further asked to explain what would happen if the size of the pinhole and the number of the pinholes were increased. Students are given pinhole cameras and asked to interact with them in any meaningful fashion using artificial light sources. Students complete a worksheet attempting to explain the various observed phenomena. Image inversion and increasing/decreasing size also explained.</p>	<p>Inquiry Lesson: Students conduct controlled activities with the assistance of the instructor to find simple qualitative relationship between d_i and h_i when d_o and h_o are fixed. (No measuring devices are permitted at this stage of the activity.) Students conduct another controlled activity to derive a qualitative relationship between d_o and h_i when d_i and h_o are held constant. Students write conceptual relationships such as "When d_i increases, h_i increases if all else is held constant." Students are asked to how they might conduct a controlled experiment to determine the mathematical relationship(s) between the associated variables.</p>	<p>Inquiry Lab: Students are engaged in conducting controlled experiments using a meter stick and ruler a means for quantifying data. The lab activity is "jig sawed" so that several simple relationship from the inquiry lesson can be evaluated. For instance, one group will find the relationship between d_o and h_i when d_i is held constant. Another group will find the relationship between d_i and h_i when d_o is held constant. The first group will find an inverse relationship; the second group will find a proportional relationship. Drawing these relationships together, and looking at the system parameter of h_o, students find with the assistance of the teacher that:</p> $\text{magnification} = \frac{h_i}{h_o} = \frac{d_i}{d_o}.$ <p>(A negative sign can be introduced as appropriate if the distances are considered vector quantities.)</p>
	<p>Hypothetical inquiry: Students use their knowledge of geometry (similar triangles) to derive the relationship $\frac{h_i}{h_o} = \frac{d_i}{d_o}$ noting that magnification is merely a definition.</p>			

Table 1. A sample learning sequence addressed more fully by Wenning (2011).

Idealized Lesson Plan Framework

- A. *Guiding Question(s):* The goal of the science lesson should be inquiry oriented. Students' attention should be focused on answering one or two key questions based on empirical evidence. State these questions. Remember that a teacher simply asking lots of questions does not constitute an inquiry-oriented lesson.
- B. *Student Performance Objective(s):* What, more specifically, are the students expected to know and be

able to do at the end of the lesson? You can only assess these objectives through observable performances. Include assessments for content knowledge, intellectual skills, and dispositions as appropriate. Students must be made aware of day-to-day objectives.

- C. *Science Content and Standards:* List here the order of science content as it will be taught as well as the corresponding Illinois Learning Standard(s). Please cite similar to the following: 13A1c for ILS objectives and "Working in Groups" for ILS Applications of Learning.

- D. *Alternative Conceptions:*** List here any alternative conceptions (preconceptions that students might bring to this subject matter and misconceptions that they might develop during class) as a result of studying the content of this lesson. Be certain to cite your reference(s).
- E. *Instructional Approach(es):*** Indicate which active learning strategies you will employ in this inquiry-oriented lesson such think/pair/share, problem/project based learning, concept mapping, interactive demonstrations, simulations, microcomputer-based labs, whiteboarding with Socratic dialogues, case study, discussion, student summaries, etc. Good inquiry-oriented lessons also will include activities from each of the three following categories: individualized, small group, and whole group.
- F. *Introduction:*** Link the current lesson with any previous lesson that is somehow related. The anticipatory set is included to ensure that the students are ready for this lesson as the next lesson in a series of lessons. These introductory activities focus student attention, provide for review or a very brief practice on previous objectives, and develop readiness for the current lesson. This is a good time to develop fundamental concepts and to elicit and address students' alternative conceptions.
- G. *Instructional Activities and Accommodations:*** List instructional activities to help all students (including those with disabilities) accomplish the stated objectives. Include estimated times for each activity and how you will address special needs. Students should be actively engaged in the construction of knowledge on the basis of empirical evidence. Be certain to see the Inquiry Lesson Scoring Rubric for pertinent teacher and student behaviors as they relate to inquiry-oriented lessons.
- H. *Checking for Understanding:*** How will you as teacher determine if the student performance objective(s) for the day's lesson has been achieved? How will you assess the objectives in an informal though meaningful manner? Recall that performance assessment must be observable and ideally will extend to all students.
- I. *Extensions:*** Explain how you will teach explicitly about the nature of science, its unifying concepts, the philosophy of science, issues of science and technology and/or the processes of science during your lesson if appropriate.
- J. *Homework:*** What projects or homework activities will you assign to your students to help them internalize and better understand the intended learning of this lesson?
- K. *Materials and Safety:*** What materials will you need to teach your lesson? Do any of your materials represent a safety hazard? If so, what precautions will you take to minimize hazards and otherwise protect your students?
- L. *Backup Plan:*** No lesson plan should be written without considering the possibility that students will complete their tasks faster than expected. Every lesson plan should, therefore, include meaningful back up activities. The backup plan should not consist of having students work on an assignment intended for homework.
- A *lesson plan* scoring rubric based on the above criteria is currently in use at Illinois State University. It can be used for self-assessment and is available for download at: http://www.phy.ilstu.edu/pte/311content/lessonstudy/lesson_plan_scoring_rubric.pdf.
- A parallel *inquiry lesson* scoring rubric is also available from the ISU Physics Teacher Education web site <http://www.phy.ilstu.edu/pte/311content/inquiry/Inquirylessonscoringrubric.pdf>. This rubric provides addition guidance for developing and teaching of an inquiry-oriented lesson. In this latter rubric the teacher is expected to:
- promote student thinking and critical questioning,
 - engender debate and discussion among students,
 - focus on one or two major questions as the guide to inquiry,
 - provide a variety of levels and paths of investigation,
 - serve a mentor and guide, giving as little direction as possible,
 - promote an active quest for new information and ideas,
 - maintain a classroom atmosphere conducive to the inquiry process, and
 - place emphasis on "How do I know the material of this course?"
- Khan (2009) provides a number of excellent examples of inquiry-oriented lessons based on thermodynamics that include hypothetical inquiry and can serve as the basis of lesson development.

Conclusion

The Levels of Inquiry Model of Science Teaching provides an instructional framework that helps to ensure that students develop a broader range in intellectual and scientific process skills. Teachers help to ensure this learning by moving students through the 5-stage learning cycle associated with each of the levels of inquiry. The reader is referred now to the Appendix of this article in which numerous examples of learning sequences are provided.

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References:

- Khan, M. A. (2009). Teaching of heat and temperature by hypothetical inquiry approach: A sample of inquiry teaching. *Journal of Physics Teacher Education Online*, 5(2), 43-64.
- Wenning, C. J. (2001). A variation on temperature conversion. *The Physics Teacher*, 39(7), Washington, DC: American Association of Physics Teachers, 434.
- Wenning, C. J. (2005a). Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *Journal of Physics Teacher Education Online*, 2(3), 3-11.
- Wenning, C. J. (2009). Scientific epistemology: How scientists know what they know. *Journal of Physics Teacher Education Online*, 5(2), 3-16.
- Wenning, C. J. (2010). Levels of inquiry: Using inquiry spectrum learning sequences to teach science. *Journal of Physics Teacher Education Online*, 5(4), 11-19.
- Wenning, C. J. (2011). The Levels of Inquiry Model of Science Teaching. *Journal of Physics Teacher Education Online*, 6(2), 2-9.