Socratic Dialogue Inducing (SDI) Laboratory Workshop*‡

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I. What Is an SDI Lab?

Socratic Dialogue Inducing (SDI) Labs emphasize hands-on and heads-on experience with simple mechanics experiments and facilitate interactive engagement of students with course material. They are designed to promote students' mental construction of concepts through:

1. conceptual conflict,
2. kinesthetic involvement,
3. extensive verbal, written, pictorial, diagrammatic, graphical, and mathematical analysis of concrete Newtonian experiments,
4. repeated exposure to experiments at increasing levels of sophistication,
5. collaborative peer instruction,
6. Socratic dialogue with instructors.

SDI Labs have been thoroughly described in the literature [Hake (1987, 1992, 1998c, 2002a,b); Galileo Project (2002); Tobias & Hake (1988); Hake & Wakeland (1997)]. They emphasize simple hands- and heads-on mechanics experiments and facilitate interactive engagement of students with the laws of mechanics. They were originally inspired [Hake (1991)] by the work of the late Arnold Arons (1990, 1993) and embody many of his instructional methods. Arons's methods were, for the most part, empirically derived but are consistent with much of the recent research in cognitive science [see, e.g. Bransford et al. (1999), Redish (1994), Heller (1999)] and some of the ideas of Socrates, Plato, Montaigne, Rousseau, Dewey, Whitehead, and Piaget. Ken Heller (1999) classifies SDI labs as "DT + CA", where "DT" stands for "Developmental Theory," originating with [see Hake (2002c) for the following references] Piaget (Inhelder & Piaget 1958, Gardner 1985, Inhelder et al. 1987, Phillips & Soltis 1998); and "CA" stands for "Cognitive Apprenticeship" (Collins et al. 1989, Brown et al. 1989).

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The ground rules for SDI Labs can be found in SDI Lab #0.1 (distributed at the workshop). As employed at Indiana University, there are two Socratic dialogists (instructors) and twenty-four students divided into six groups in an SDI Lab meeting. The student groups are seated around tables so that group members can interact easily. Students work through lab manuals that encourage active student thinking and involvement by establishing certain requirements for the students. They record their work in workbooks during the lab meeting and hand in these workbooks at the end of each period. The books are annotated and returned at the next lab period, but not graded. Students' lab grades are determined from periodic written exams containing questions that probe students' conceptual understanding of experiments similar to those performed in the lab.

II. SDI Lab Benefits

Socratic Dialogue Inducing (SDI) labs have been shown by pre/post testing to be one of the more effective methods for enhancing students conceptual understanding of Newtonian mechanics (see Sec. III). In addition to emphasizing concepts, SDI Labs are designed to enhance students':

1. understanding of the nature of science;
2. use of effective strategies for scientific thinking and problem-solving; and
3. research skills such as collaborative effort, drawing, written description, thought experiments, modeling, consideration of limiting conditions, experimental design, control of variables, dimensional analysis, and solution of real-world problems.

Among other advantages SDI Labs, they:

a. are adaptable to a wide range of student populations - middle school, high school, college, university, non-physical-science university professors;

b. are well received and popular with students;

c. are easily modified to suit local conditions and *are transportable across cultures since native Socratic dialogists can tailor the dialogue to suit native-student knowledge and experience*;

d. are inexpensive as far as equipment costs are concerned;

e. diminish the impersonality of large-enrollment introductory classes;

f. are compatible with other interactive-engagement methods;

g. may be inserted as the lab component in otherwise traditional courses so as to enhance student interactivity and conceptual understanding;

h. provide good training grounds for instructors who discover undreamed of learning problems when they "shut up and listen to students";

i. are good examples of inquiry or "guided construction" learning for prospective teachers;

j. are a source of valuable research data on physics learning, particularly if pre/post testing is carried out and dialogues and conversations are recorded and analyzed.

III. Evidence for the Effectiveness of SDI Labs

Over a ten-year period at Indiana University (IU), SDI Labs were integrated into courses in which lectures, discussions, and exams emphasized conceptual understanding and interactive engagement. Lectures usually employed a standard textbook and back-of-chapter problem assignments and, after 1993, included "Concept Tests" (Mazur 1997); discussion sections were devoted to cooperative group problem solving under Socratic guidance. The IU courses enrolled a total of 1263 students (primarily pre-medical and pre-health professional) and achieved an average normalized gain (Hake 1998a) on the conceptual Halloun-Hestenes tests of $\langle g \rangle_{IU} = 0.60$, considerably higher than the average gains of other courses considered in the survey (Hake 1998b, 2002c): $\langle g \rangle_{T} = 0.23$ for 14 traditional (T) courses, and $\langle g \rangle_{IE} = 0.47$ for 43 non-IU interactive (IE) courses. The Hestenes-Wells Mechanics Baseline test of problem solving was also administered in two of the IU courses. The course average score was 58%, close to the 62% for 11 other interactive engagement courses of Hake (1998b).

SDI Labs or portions of them have also been used successfully in middle schools (Priestley 2002), high-schools [Hake (1998b), Butterworth (2002)], and community colleges (Uretsky 1993); and with elementary education majors (Hake 1991), physics majors (Wakeland 1992), and non-physical-science professors (Tobias & Hake 1988). There is some evidence that SDI Labs at IU are:

(a) more effective when coupled with a physics-education-research-based text [Reif's (1994) *Understanding Basic Mechanics* was used in IU94S (Hake 1998b))], and

(b) less effective when grafted onto courses in which lectures, discussions, and exams are of the more traditional type.

IV. What Are the Requirements?

1. Conventional physics lab environment (e.g., 24 students per lab, 4 at each of 6 tables) except that it is better to have two instructors in one lab section.
2. Grade incentives for taking the SDI labs seriously, e.g., exam questions which test conceptual understanding of SDI lab topics.
3. Education of instructors, preferably through apprenticeships with seasoned dialogists.
4. SDI Lab Manuals - Nine portable-document-format (pdf) files are at < http://www.physics.indiana.edu/~sdi >. The electronic availability of manuals has the advantage that they may be easily updated; and instructors with computers can easily copy, cut, paste, and delete so as to modify them to suit their own pedagogic styles, equipment, and curriculum. Considerable selectivity can be exercised because most of the labs contain more material than can be covered in two 2-hr lab periods.
5. Teacher's Guides for SDI Labs #0.2 and #3 are available for downloading at the Galileo Project (2002). Others, including Guides for SDI Labs #1 & #2, will soon be available at the same site.

V. Sri Lanka Workshop

The 24 active participants in the workshop attempted to work through the following sections of SDI Lab #1, just as if they were students:

> Sec. I . "How to Draw a Force Vector," "How to Determine the Newton's Third Law Action-Reaction pair," "Idealized Models," "How to Learn as You Proceed."
>
> Sec. III . "Forces Exerted on a Disk by Your Hand - while at rest, moving the disk vertically upward at constant speed, moving the disk vertically upward at uniformly increasing speed, carrying the disk at a constant horizontal velocity.
>
> Sec. VII. "Forces on a Kid in a Truck" - Can a truck driver pin kids to their seats by driving at a very high constant vector velocity **v**? (In the last ten minutes of the workshop we showed a videotape of dialogue with students struggling though this section at Indiana University.)

How could such juvenile activities be of any value? Nick Steph (1991) (new, at the time, to active learning pedagogy) of Franklin College in Indiana wrote:

> The efficacy of these labs . . .(SDI #1 & 2). . . is truly remarkable. To read them cold, they seem so simple, even trivial. To observe an SDI lab, with no sound, it looks like not much is being accomplished; no fancy equipment, just a few masses being moved and shoved about. But, turn on the sound and you hear the big difference: the students in each group are talking and discussing, often with great animation, their interpretation of the experiments. The labs are well crafted to elicit the major student misunderstandings such as "forces of motion," . . . as described in Hake (1992). . . as well as the difference in use and meaning of the three laws. The first time I tried these labs was an amazing experience. After getting the students started, I left the room for about fifteen minutes. When I returned, I found the room was filled with sixteen modern day Aristotles, *each arguing eloquently that if an object is moving there must be a force on it.* And this was *after* two lectures on Newton's Laws. Then many Socratic dialogues ensued and slowly the students came over to the Newtonian description of force, *with* understanding. They finally understood that action-reaction forces of the third law act on different bodies and, perhaps best of all, force is an interaction between two bodies and not a thing that may be possessed by a body.

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