

Practical experience for people who want to implement ISLE in a university introductory physics course. The long version.

By David Brookes

1) Before you start, **articulate the learning goals** you have in mind for your students. I have implemented ISLE and observed others try to implement it. And I can say for certain, if you don't understand the philosophy of ISLE and buy into this philosophy, your course will never succeed with the ISLE format. This is not a demand that you think a certain way. If your course goals are not matched by the goals of ISLE, I think it is better to take a different teaching approach than try to implement ISLE half-heartedly and fail.

Before I taught the ISLE course, I gathered the members of my research group, sat them all down and asked them to help me clearly articulate what the goals of my physics course would be. I asked them to help me think about what we wanted our students to be able to do by the end of the physics course and whether we wanted any of what they've learned to stay with them through their lives.

Some possible goals of a physics course are a) get students to learn a bunch of physics concepts, b) get students to pass a standardized test c) increase students' physics knowledge. Now, here is the problem: ISLE does not directly address any of these goals although the happy by-product of student who have learned by the ISLE method is that their knowledge and conceptual understanding are often far superior to students taught by other methods that focus on conceptual understanding as their primary goal.

The primary goal of ISLE is a *process* goal (acquire scientific abilities, learn to think like a physicist) rather than a *substance* goal (acquire knowledge). There are many reasons why this is a good goal to have, but there is not enough space to fully justify it here. In practice the goal if ISLE is to engage students in the process of doing physics as real physicists do it. This is a really powerful goal because the scientific process abilities that students learn are abilities that can be transferred to other life endeavors. Think about it, when in your life do you really need to understand the intricacies of Newton's second law? However, how often are we confronted by a news report with a scientific claim that needs to be examined critically and scientifically? It is the scientific process abilities (for example, being able to ask, what assumptions did this person make in coming to their conclusion?) that are useful life skills, not the dry facts of physics knowledge.

Why is it important to start with goals? It is important because the goals you have for your physics course necessarily influence the types of assessment you use for your students and the types of activities that you give them. For example, it is mistakenly believed, in spite of vast evidence to the contrary, that making students solve "back of chapter" physics problems enhances their scientific reasoning abilities. In reality students learn sets of rules by which to apply the formulas they've memorized or have in front of them on a formula sheet. Abilities like making sense of a situation, questioning

assumptions, and evaluating answers are often lost or forced into the background by the more important goal of getting the “right” answer in a limited amount of time.

2) Recognize that **education is a holistic system**, not a series of interventions or a recipe of things you should do. There is no recipe! However, like a great chef, a good teacher knows which ingredients work together best to make a complete whole. These are: learning/teaching goals, teaching methods/plans/strategies, students’ knowledge and epistemological beliefs, student motivation, and most importantly, assessment instruments. All these elements are parts of a strongly interacting system. When these all work together, beautiful harmony can result. When these elements are in conflict, not much learning takes place.

3) **Plan ahead**, way ahead. ISLE is all about coordinating the epistemological elements of physics. From a teaching perspective this means that labs, recitations and lectures must all form part of a coordinated whole that becomes part of the *process* of students’ knowing. A practical example: when I did induction and Lenz’s law, I made sure that students did an observation lab *before* they came to the first lecture on the subject. Their job was to discover what factors affected electro-magnetic induction. Some figured it out, some didn’t, but they all came to Monday’s lecture ready to learn about it. I found it effective to have all labs and lectures planned ahead before the semester started. In this way, everything worked together (for the most part).

4) **Content is less important in ISLE than process**. Learning takes time. By removing some content, students are able to engage in the process of developing their knowledge (like scientists) without so much time pressure. I did some “triage” on the curriculum, before the course started. For example: I spent almost no time on electric circuits except for allowing students to develop the basic idea of potential difference, current and how they are related through Ohm’s law (in some cases where the conductor is ohmic and temperature remains constant). My logic was: complex circuits (multiple resistors, Kirchoff’s rules) have very little usefulness for my audience (pre-meds and biologists). Complex circuits are also self-contained in that they don’t much affect the later physics that I DO want my students to learn about (electro-magnetic induction, electro-magnetic waves, geometrical optics, wave optics). So why not leave it out? Maybe you’re teaching electrical engineers. Maybe you can leave out optics altogether and devote more time to electrical circuits. I think that each case is different.

5) To me, **assessment** is the most important component of any physics course. If you want to teach using ISLE, you need to assess for what ISLE wants students to learn. Problem-solving is only one component. This is what I did: I had to assign recitation activities, homework activities and write exams. For each and every activity I assigned to students, and each and every exam question, I asked myself: “Is this activity going to contribute to my learning goals. Is this activity going to assess what I REALLY wanted the students to learn (summative assessment)? Is this assessment going to HELP students to learn what I want them to learn (formative assessment)?”

ISLE is about getting students engaged in tasks that mimic the process of physicists doing physics. These tasks are both “knowledge builders,” and at the same time, help students to develop their scientific abilities. There are strategies that are known to foster students who are motivated and task involved. The most singly successful strategy is the use of formative assessment and formative self-assessment. Thus, when I teach ISLE I try to incorporate as many formative assessment tasks as I can at all points. For example: when students had homework, we graded the homework, returned it and told them that they could correct their mistakes and return their homework to obtain a better grade. Naturally some students tried to exploit this by doing a sloppy job the first time around and relying on the “rework” to improve. Simple and clear rules like “the task has to show evidence of a good attempt – there is no rework points for a task that is not attempted” helped to overcome this difficulty.

The types of activities one uses in ISLE echo the goal of trying to develop scientific abilities. For example, one scientific ability is the ability to represent a physical process in multiple ways. So instead of giving students a block on an inclined plane problem and asking them for the acceleration, I might give them a block on an inclined plane problem and ask them to draw the free-body diagram for the block. The answer is the new representation. In a more sophisticated form, I might ask students to evaluate the correctness of their FBD for the block on the plane. The goals I have for the students (improve their scientific abilities and get them to engage in the process of doing physics) directly influence what I ask them to do. Another example: Physicists never conduct “cookbook” labs. They have to design their own experiments to answer a specific research question. ISLE labs do the same. They pose a specific research question, (e.g., “design an experiment to figure out what the relationship between force and acceleration is”, or “your friend hypothesizes that an object always move in the direction of the net force exerted on it, design and conduct an experiment to disprove his hypothesis.”)

6) Lecture as a large room meeting and a time for telling. I admit that this was the least successful part of my attempt to implement ISLE. I suspect this is mainly because I am a novice lecturer and it is something that does not come easily to me. What I tried to do and wish I could do even better is the following:

a) I tried to turn lecture into a big discussion section. This meant doing a lot of experiments at the front, and asking students to suggest possible explanations for what they observed. Sometimes I would do a testing experiment. A trick I learned here was to explicitly ask students: “what does model X predict the outcome of this experiment will be?” rather than “what do YOU predict the outcome of the experiment will be?” This rephrasing of the question does wonders for students’ reasoning process and epistemological beliefs.

b) I tried to use lab and recitation to prepare students for learning in lecture. Observation type experiments are very important in this process. I tried to summarize for students what they should have seen in lab last week and then I would try and draw their observations together and help them see the point of what ever model or explanation was considered the best explanation of the phenomena they had observed. (A time for telling.) If students had done testing or application experiments in lab, I tried to start out the lecture week with observation experiments in the lecture itself.

c) I cannot overemphasize the need for clarity. Tell the students where you are taking them, and why. And when they have gotten to where you want them, tell them again where you've taken them, where they are and why they are there. I don't know how else to say this.

7) **The reality - the problem and promise of epistemological ought.** It would be nice if students would see the point of ISLE and jump right in, and start thinking like physicists, designing experiments, evaluating their results, thinking about their experimental or theoretical assumptions, conducting sophisticated analysis of sources of uncertainty. It would be nice if students asked the "how" and "why" questions (the epistemological questions they ought to ask) however, the reality is that in most cases, before you get your students, they have been subjected to an endless string of science and math courses that have eroded their natural desire to think and reason independently and creatively. In most cases it is simply easier for students to learn for a standardized test that tests memorization, regurgitation and little, if any, thinking, and certainly not any creativity. I found that it takes at least four to five weeks before any substantial number of students are willing to play the ISLE game, rather than the familiar one they are used to. I cannot make many suggestions here except that one needs to stick at it. By the end of the semester, some students had undergone a complete transformation in how they thought and reasoned. For me, that was my reward.

Oh, and one last thought. In ISLE, the most learning happens in recitation and lab, not in lecture. You can't do anything without an amazing team of TAs. How you get them on board, that's for you to figure out.