Using POE Sequences

POE sequences provide an important way to enhance your students' understanding of important scientific ideas. We believe that POE sequences are an important tool in every science teacher's repertoire. If you are teaching a traditional curriculum, one based on a textbook, the sequences can enliven the enrichment you provide. If you are teaching an activity-based curriculum, they can help provide a firm basis for understanding. POEs are based on a sound theoretical foundation that has been researched extensively.

Children live in a world of sense impressions. They see, hear, smell, touch, and taste. From infancy they spontaneously make sense of the world in which they live. They form concepts and try to link one concept with another to explain the world around them. For example, they might come to think that matter disappears when substances dissolve or burn, or that plants take in food through their roots, or that heavy objects such as stones or nails sink, or that heavy objects fall more quickly than lighter ones. They find such ideas useful in their lives. The idea that children—or all of us, for that matter—construct such understandings of the world is fundamental to the constructivist view of learning.

Scientists also try to make sense of the natural world of sense perceptions. This is their collective mission. They do this deliberately and carefully. They extend our sensory world by using instruments to measure mass, length, and time more accurately. They use instruments to measure the large and the small, the hot and the cold, the soft and the loud, and so on, to enhance our sensitivity. They expand the natural world by carrying out experiments, enabling them to observe phenomena that do not occur naturally. They formulate concepts such as density and gravitational force and arrive at powerful generalizations, such as that an object floats when its density is less than that of the liquid in which it is immersed, or the acceleration of all falling objects is the same in a vacuum.

There are thus two types of interpretations of the world in which we live: everyday, commonsense interpretations and those of the community of scientists. It is part of a science teacher's job to help each student build on everyday, commonsense interpretations so that the student can adopt and internalize scientists' interpretations. This can be a very challenging task, especially when the scientific interpretation is at odds with students' interpretations. For example, some students believe that electricity gets used up as it goes around a circuit, or that vacuums suck. These ideas have worked well for the students concerned. So why should they change their ideas now?

How can the science teacher respond to this challenge? A variety of teaching strategies have been developed to complement the constructivist view of learning. As you would expect, they have many features in common. The POE sequences we have developed embrace many of these features. They are included in the suggestions for using the POEs that follow. As you read about the steps in the sequence, you might find it useful to refer to one or two POEs to provide examples.

Step 1: Orientation and Motivation

The POE usually begins by drawing on the students' past experiences or previous understanding and raises a challenging question that can be addressed through the experiment that follows. A few minutes of full-class discussion will provide the students with the opportunity to reflect on their past experiences and understanding.

Step 2: Introducing the Experiment

Introduce the experiment. Linking it to the previous discussion will help make it meaningful.

Step 3: Prediction: The Elicitation of Students' Ideas

Before doing the experiment, ask the students to write down on the worksheet what they predict will happen, along with the reasons for their predictions. This exercise is valuable for both the students and the teacher. Making their reasons explicit helps the students become more aware of their own thinking. It also provides the teacher with useful insights and an opportunity to plan ahead. Hence, while students are writing, you might stroll around so as to prepare yourself for the discussion that will follow.

Step 4: Discussing Their Predictions

This is a two-stage process. First, ask your students to share their predictions in full-class discussion, using a chalkboard or SMART Board to highlight the range of predictions and reasons for them. This needs to be handled with sensitivity on account of some students' feeling anxious about seeming "wrong." Hence, you will need to be supportive and encourage as many students as possible to express their viewpoints. There are no poor ideas! All ideas are valued because they represent our best efforts to make sense of the world. You might explain that making our predictions explicit helps us learn.

After this has been done, you might invite the class to discuss which predictions and reasons they now think are best. When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it's often fun and illuminating to have a straw vote about the outcome.

Step 5: Observation

Most of the experiments in this book are designed to be done as demonstrations, although some make good student explorations. If you demonstrate the experiment, invite the students to help out whenever appropriate. Ask them to write down their observations.

Step 6: Explanation

Students often reshape their ideas through talking and writing. We have frequently found that it's useful for students to discuss their explanations of what they observed with a neighbor or in a small group before formulating a written explanation. They seem to find this action reassuring. After they have done this, collect a sample and invite a full-class discussion of these as appropriate.

Step 7: Providing the Scientific Explanation

Introduce the scientific explanation by saying, "This is what scientists currently think," rather than, "This is the right explanation." Many teachers choose to ask their students to write the explanation in their notebooks or on the back of their activity record sheets. The students might then be invited to compare their explanations with those of scientists, looking for similarities and differences (another opportunity for them to reconstruct their ideas).

Step 8: Follow-Up

Researchers have found that students' ideas often are resistant to change and there is no guarantee that a POE will do the trick, even though it might provide a valuable beginning. This also was evident in the field testing, when student explanations before and after the experiment were compared. Hence, in some POEs, we have included a follow-up at the end. This often is designed to help the students reconsider or apply the scientific ideas they have just encountered and begin to appreciate how useful they are for explaining natural phenomena.

So many steps may seem to make POEs complex and unmanageable, but this isn't the case in practice. The underlying pedagogy resonates with the beliefs held by most teachers, and after a little experience you will probably find the procedure becomes routine for both you and your students. This is liberating and will enable you to focus your attention on facilitating learning by responding to your students. Incidentally, many teachers have found that they can complete Steps 1 through 7 in a 40-minute period. Sometimes they take a break after Step 5: Observation, and set the next step for homework.

A major strength of POEs is that they can continuously provide you with insights into your students' thinking: Steps 1 through 4 probe your students' initial conceptions, Steps 6 and 7 enable you to monitor your students' efforts to reconstruct their thinking, and Step 8 provides you with feedback on your students' progress. POEs thus can offer you "authentic responses" from your students, provided that judgment and assessment do not come into play. It's important, therefore, to encourage your students to share their thinking, which for the time being may or may not be scientifically acceptable, and to value their responses. In this way, it becomes possible for you to adjust the pace of your teaching and to plan for subsequent instruction, thus optimizing your effectiveness.

The Teacher's Notes

Alongside each POE, you will find the scientific explanation; students' explanations: field experience; students' explanations: research findings; and apparatus and materials.

Scientific Explanations

We have tried to express these in a student-friendly form, one you might choose to use in Step 7.

Students' Explanations: Field Experience

These might well be worth reading before you use the POE because they can help you anticipate what your students might say. Even though your class of students will be unique, it could well be that they will have similar ideas to those we have found. On account of the way in which the field testing was conducted, it was not possible to provide these students' explanations for all of the POEs. In these cases, we hope you might make time to analyze some of your own students' scripts.

Students' Explanations: Research Findings

The research findings similarly provide you with an idea about the responses that your students might give, and you might find it interesting to check these out not only before but also after using a POE. When you do this, you will be locating your personal experience alongside the body of knowledge about teaching, and this can be professionally enriching.

In most cases, we expect that you will find it sufficient to simply refer to these summaries. However, some teachers, perhaps those engaged in further study, might find it worthwhile to go into greater depth. As was mentioned before, this area has been extensively researched, and literally hundreds of papers have focused on children's ideas. *Making Sense of Secondary Science* (Driver et al. 1994) is a wonderful resource that summarizes the findings through the date of publication. These days, the research literature is much more accessible, and fortunately this has removed much of its esoteric nature. Accessibility of the literature has been made possible by the arrival of Google Scholar. If you have a reference, you may view a summary or abstract of the article simply by filling in a few key words on the Advanced Scholar Search page. Sometimes the whole article is available, but if it is not and the article looks promising, many libraries, especially university libraries, will be able to help you access it. (A comprehensive bibliography of students' and teachers' conceptions and science education up to 2009 by Reinders Duit is available online: *www.ipn.uni-kiel.de/aktuell/stcse/stcse.html*.)

During the field testing, we were intrigued to find many similarities between our experience and these research findings, and it was illuminating to compare the two. Because many of our POEs and elicitation procedures are original, we have incidentally added to these findings. Moreover, we hope that in the future some teachers will take time to analyze their students' scripts, especially where we weren't able to do so, and thus add to this body of work by becoming researchers themselves.

Apparatus and Materials

Teachers often have difficulty acquiring and storing the necessary apparatus. With this in mind, we have tried to keep the requirements simple and have recommended the use of everyday items wherever possible. We would like to offer these two ideas, which may help teachers overcome the problem:

1. You might organize a curriculum night for parents featuring POEs. We are confident they would enjoy participating in a simulation of one or two sequences themselves. At the end, you could solicit their help in acquiring the materials you need, dividing up the apparatus and materials lists between them.
2. We have found that shoe boxes, fish trays, and other similar containers are useful for storing the items needed for most POEs. They can be labeled and kept on a shelf, ready to use at a moment's notice.

Finally, a few comments about your use of the student activity sheets. It is our intention that teachers who own this book should be free to copy the activity sheets for their own students' classroom use. To facilitate this, the publishers selected a binding that makes it possible to easily open the book and keep it flat. However, we gather that in some schools and districts there are strict policies about making limited photocopies. In such cases, many teachers have reported that they copy the student POE pages onto overhead transparencies or PowerPoint slides and have students answer the questions in their notebooks. To us, this would not be as effective for learning; we carefully considered the layout and space allotted for writing to enhance student engagement and provide students with a record of the activity. Nevertheless, it certainly helps overcome the problem.

Reference

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science*. London and New York: Routledge.

Safety in the Classroom Practices

Although most of the experiments are designed to be done as demonstrations, some make very good student explorations. It is important to set a good example and to remind students of the pertinent safety practices when they do perform an experiment.

1. Always review Material Safety Data Sheets (MSDS) with students relative to safety precautions in working with hazardous materials.
2. Remind students to only view or observe animals and not to touch them unless instructed to do so by the teacher.
3. Use caution when working with sharp objects such as scissors, razor blades, electrical wire ends, knives, or glass slides. These items may cut or puncture skin.
4. Wear protective gloves and aprons (vinyl) when handling animals or working with hazardous chemicals.
5. Wear indirectly vented chemical splash goggles when working with liquids such as hazardous chemicals. When working with solids such as soil, metersticks, glassware, and so on, safety glasses or goggles can be worn.
6. Always wear closed-toe shoes or sneakers in lieu of sandals or flip-flops.
7. Do not eat or drink anything when working in the classroom or laboratory.
8. Wash hands with soap and water after doing the activities dealing with hazardous chemicals, soil, biologicals (animals, plants, etc.), or other materials.
9. Use caution when working with clay. Dry or powdered clay contains a hazardous substance called silica. Only work with and clean up clay when wet.
10. When twirling objects around the body on a cord or string, make sure fragile materials and other occupants are out of the object's path.
11. Use only non-mercury-type thermometers or electronic temperature sensors.
12. When heating or burning materials or creating flammable vapors, make sure the ventilation system can accommodate the hazard. Otherwise, use a fume hood.
13. Select only pesticide-free soil—commercially available for plant labs and activities.
14. Many seeds have been exposed to pesticides and fungicides. Wear gloves and wash hands with soap and water after an activity involving seeds.
15. Never use spirit or alcohol burners or propane torches as heat sources. They are too dangerous.
16. Use caution when working with insects. Some students are allergic to certain insects. Some insects carry harmful bacteria, viruses, and so on. Use only biological supply house insects and wear personal protective equipment, including gloves.
17. Immediately wipe up any liquid spills on the floor—they are slip-and-fall hazards.