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This section focuses on the education of science teachers, and aims to communicate ideas and strategies which will assist science teacher educators to enhance and enrich their programs.

THE STARTER EXPERIMENT APPROACH (SEA) TO TEACHING CHEMISTRY AND PHYSICS IN THE PHILLIPPINES AND INDONESIA AND THE REST OF THE WORLD

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Preface (Ed van den Berg)

What do you do in a country where experiments are rarely used in Physics and Chemistry and where science is taught mainly verbally and frequently without textbooks but with an overcrowded curriculum, to classes of 45-65 students, where equipment is lacking, where students have never experienced the thrill of investigation and discovery and where many or even most teachers were trained in a discipline other than the one they are assigned to teach? How can you then involve teachers and students in experiments and how can you train the teachers? This time we present the answers of Dr. Jürgen Schönherr, a German consultant who spent more than a decade in in-service training in S E. Asia. He asked me to draft an article based on a video tape of the method and his writings, and then saw the final draft, reacted, and approved.

The description provided below is particularly apt for the schools in South East Asia. However, both old and recent research data (Tamir & Lunetta, 1981; Germann et al., 1996) suggest that students are rarely made to go through the phase of conceptualization and design of experiments. Most experimentation is limited to *measuring and some standard analysis* following recipes. Here is a method which emphasizes design in a very systematic and manageable (for the teacher) and open (for the student) way.

The experiments are surprisingly simple and yet provide many opportunities for generating hypotheses which can be tested experimentally with very simple equipment (thus can be done in SE Asian classrooms). An example experiment is reported below.

Starter Experiments

In most countries overcrowded syllabi dictate what teachers do in the classroom. There is little or no room for experiments and what is taught and tested is mainly 'content' and little or nothing about the methods of inquiry. As we cannot easily change curricula, let's do something which can be done within any curriculum. The basic idea is to start a new topic or chapter with a set of experiments, and perhaps not more than 3-6 times a year, but do it well. The other lessons on the chapter can just be taught whichever way the teacher is used to. A bird's-eye view of the method is as follows:

Step 1: Students observe a demonstration experiment (here called *starter experiment*) and write observations individually.
Step 2: Observations are collected by the teacher and clarified by the students.
Step 3: The experiment is repeated to make observations more complete and to verify them.
Step 4: Students write 'attempted explanations' individually.

Step 5: Groups of students design verification/ falsification experiments.
Step 6: Groups of students execute the experiments.
Step 7: Groups of students demonstrate their experiments to each other and report results.
Step 8: Students try to write conclusions with regard to the relationships between concepts involved.
Step 9: Students document the lesson in their notebooks and teachers make sure this is done properly.

The first lesson on a new topic starts with a demonstration experiment where all students observe. The reader may wish to read the description of the starter experiment which accompanies this paper.

Step 1: Observation. Each lesson following the Starter Experiment Approach (SEA) has to 'start' from looking at nature. The teacher must bring a *bit of nature* in to the classroom. This *bit of nature* is an experiment, easiest conducted by the teacher as a demonstration experiment. Sometimes it can be done as a student experiment, but that will require more preparation time of the teacher.

The materials used for the Starter Experiment should be taken—if possible—from the environment of the students. Special science equipment will be used later in the course of the lesson when students conduct their verification/falsification experiments. The experimental set-up should be simple and clear. The teacher must see to it that each student can make detailed observations, big classes will be grouped by the teacher and the groups will take turns for observation.

I want to discourage the very common, but useless naming of parts of the experiment (common in Asia). Instead students will learn to describe things they have not seen before in their own words. The name of the part will be given later by a student or the teacher when it has already been described by the student. This way we help students to improve their communication skills.

Students **individually** write all kinds of observations. Of course some of the observations are false and some are poorly worded. The teacher does not speak during this phase. When he or she feels that the students are missing out on something important, the teacher can demonstratively go near the experiment and do this observation. Students will quickly learn to understand our body language.

Since observations are the basis of all learning, the teacher must take utmost care that all students take part in this activity. There are a number of useful methods to achieve this:

1. The Starter Experiment should not contain unnecessary items.
2. The experimental set-up should be simple and preferably composed of materials and items taken from the students' environment.
3. Students must have close access to the experiment for using as many senses for their observation as possible. The teacher must warn the students in cases where tasting, smelling, or touching is dangerous!
4. If the class is too big to allow all students close observation (classes in the Philippines can be 60 students or more) the teacher should group the class and let them take turns for observing the experiment (or use more than one set-up).
5. If necessary, the teacher must repeat the experiment to allow all students to observe properly.
6. Students should be advised to write all their observations down, preferably each observation on a separate piece of scratch paper. It is a good idea to let the students number their observations.
7. Students must not talk during the observation phase nor copy each others observations (somehow this is more easy to control in Asia's big classes than in European small classes).

After all students have finished writing down their observations, the teacher starts to collect them. Again all students can take part in this activity if the teacher observes the following procedure:

1. One student is asked to read the first observation from her/his scratch paper.
2. The teacher takes this observation and asks who has noted the same thing, even using another formulation and collects them without reading them again.
3. One representative of the first observation is displayed on the board, either by writing it, or—to save time—by sticking students' scratch papers on the board.
4. In the same manner, all the other observations are collected and for each new observation, one representative is displayed on the board, organized under each other in one column.
5. The teacher must watch out not to accept attempted explanations as observations. During the first few times the SEA is used, students usually have difficulties to understand the difference between an observation and an explanation.

Steps 2 and 3: After some discussion of the observations, the demonstration experiment is repeated to verify selected observations. Improvements of formulations should be made here if necessary, wrong observations are taken out or replaced by correct ones, missing observations are added. Students should now be given some time to sketch the experiment and note the observations into their notebooks. In the meantime the teacher selects those observations which are related to the concept and marks them by giving them big numbers. (In order not to discourage the students, the teacher must stress that observations not being selected are not bad or rejected, but that not all observations can be taken up at the same time and that some observations need not be explained since they are evident or trivial.)

Step 4: In this phase of the lesson again the students are working individually. For each of the selected observations they try to explain why these phenomena happen or can be observed. The students are asked to use separate pieces of paper for each attempted explanation. The teacher should stress at this point that it is not important that the attempted explanation of a student is 'correct,' but that it is important that each student must try to explain the phenomena with her/his own words and by her/his own ideas. Again the teacher must discourage the students to discuss their ideas or copy from each other.

Thus, the teacher has the opportunity to get to know students' pre-concepts (a rare opportunity in lessons following traditional methods). This knowledge is important to actually confront the pre-concepts of the students with the more scientifically acceptable concepts at later stages of the lesson. Piaget nicely explained that the learner must feel a need to give up the pre-concept in order to replace it by a better one (*restructuring*).

Step 5: Verification/falsification. Students are grouped and each group is given one observation with the corresponding attempted explanations. Their job is to find out experimentally which of the hypotheses (attempted explanations) is correct, which one is wrong. As long as students are not familiar with SEA, the teacher is in high demand, helping students first of all understand the task, meaning analyzing the hypothesis and determining the parameter to be controlled (changed) and the other parameters to be kept constant (not changed). Inputs regarding equipment and procedure are also much needed in the beginning.

If possible the groups should not exceed five students, groups of three members are optimal. In case there are not enough observations, the attempted explanation for one or more observations can be split and given to two groups for verification/falsification. It is also possible to have two groups working parallel on one and the same set of attempted explanations.

I often observe that teachers have prepared verification/falsification experiments in advance, even sheets with the cookbook style procedure for the experiments were given to the groups. Though it is strongly suggested that teachers should try to anticipate the lesson they are planning, I would like to discourage the habit of 'thinking for the students.' Giving the students a ready made verification experiment plus the 'User's Manual' is depriving them of a very important step of the SEA, the design of a veri/falsi experiment on the analysis of the attempted explanations. This very task is boosting students' creativity, it cannot be skipped!

Step 6: Experiments are carried out. After the design and procedure for the 'veri/falsi' experiment have been approved by the teacher, the students collect the necessary equipment and start setting up the experiment. If sensitive equipment is involved, the teacher should require students to have their set-up inspected before starting the experiment. The teacher should always mention necessary precaution measures and give hints on how to conduct the experiment and how best to collect the data.

After conducting the experiment, the students have to write a summary on a big sheet of paper to prepare for the report to the class about their experiment and findings. The experimental set-ups will only be dismantled after the groups have given their reports.

Step 7: When all groups have finished their work, the teacher will ask all students to gather around the table of the first group. The group members will explain what they have done, starting with the original observation and ending with the findings of their veri/falsi experiment. The class then will have to interpret the results and decide whether the attempted explanations are correct or false.

The activity will be repeated until all groups have reported and all hypotheses have been assessed.

Step 8: Formulation of the concept. The teacher will ask the students to try writing draft formulations and conclusions for the concept(s) individually. For students still unfamiliar with the SEA it is helpful to collect some key-words first, noting them on the board. The students should be allowed to use their mother tongue if they have difficulties to translate their ideas into the official medium of instruction. The translation can be done later and will serve the students as an additional language training!

For the final formulation of the concept, students and teacher will work together. It will be written in a prominent way on the board. Concept mapping might be appropriate at this stage.

Step 9: Fixing the lesson in students' notebooks. At an earlier stage, the students have already sketched the Starter Experiment and noted the observations. Now they will add the attempted explanations and the veri/falsi experiments by copying them from the report sheets of the groups being displayed in the classroom and the final formulation of the concept.

The teacher should make the students understand that this work of documenting the proceedings of the lesson is important, because it constitutes a reference for them for the future. Students who do a good job at keeping good lesson records should be singled out for praise. Please note that this is even extra important in classes where many students do not have textbooks.

Postscript (Ed van den Berg)

In the hands of good teachers, the SEA works very well in the classroom, even in the large classes in the Philippines and Indonesia. However, it does require sufficient time for training and it does require a certain minimal level of subject matter mastery. Without that teachers do not feel confident to use it. In a future article we hope to report more on teacher training methods. Schönherr has developed a certain training strategy he calls the "Model-Transfer-Strategy" which was developed over the years and has turned out to be effective in developing countries.

Endnotes

1. The Starter Experiment Approach and the accompanying teacher training strategy were developed while the first author worked at the National Science Teaching Instrumentation Center (NSTIC), Sudlon, Lahug, Cebu City, Philippines. NSTIC is a joint effort of the Philippine and German governments.

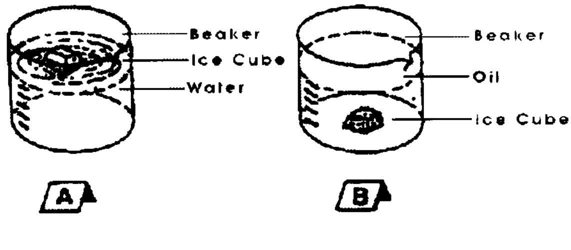
References

Germann, P. J., Haskins, S., Auls, S. (1996). Analysis of nine high school biology laboratory manuals: Promoting scientific inquiry. *Journal of Research in Science Teaching, 33(5),* 475-499.

Tamir, P., Lunetta, V. N. (1981). Inquiry-related tasks in high school science laboratory handbooks, *Science Education, 65,* 477-484.

Figure 1

Beaker A: Water with ice cube
Beacker B: Oil with ice cube



Lesson 1: The Starter Experiment

The teacher simultaneously places an ice cube of similar size into each of the 2 beakers, one containing water and the other containing an equal volume of cooking oil (Figure 1). Please do not explain the set-up like "This is a beaker, it is filled with water, that is an ice cube." All these are part of your students' observations!

A list of possible observations could be as follows:

There will be possible explanations with regard to the following questions:

a) *Why do the levels of the liquids in both beakers rise when ice is placed?*
b) *Why does ice float in liquid A and sink in liquid B?*
c) *What causes the formation of bubbles when ice is placed in liquid A?*
d) *Why do bubbles rise faster in liquid A than in liquid B?*

Beaker A	**Beaker B**
1. Liquid is colorless, odorless and tasteless. 2. The level of the liquid rises when ice is placed in it. 3. Ice floats in the liquid. 4. Bubbles generate from ice and while increasing in size move rapidly upward to the surface. 5. The container feels cold. 6. Moisture appears on the outside surface of the container. 7. Ice completely melts within 3 minutes. 8. A single-phased liquid is observed.	1. Liquid is greasy, yellowish and smells fragrant. 2. Same observation as in beaker A. 3. Ice sinks in the liquid. 4. Tiny bubbles from somewhere near the surface fall very slowly towards the ice. 5. Fine white particles accumulate or hold on to the exposed surface areas of the ice, forming a cotton like appearance. 6. The outside surface of the container remains dry. 7. The bottom of the container feels colder than its upper portion. 8. Bubbles generate from ice, one at a time and move towards the surface. 9. Ice gradually melts while solid particles of oil disperse and melt into the liquid. 10. Ice completely melts within 3 hours. 11. Two layers of liquid are formed, oil on top of water.

These are the essential observations. Students may observe other phenomena like reflections or movement of the liquid. That is fine and they should be encouraged to observe whatever there is to observe.

Actually, after the repetition of the experiment and the observations, students could sketch and describe the experiment in their notebooks and copy the observations. Then the formulation of attempted explanations could be done as home work.

Lesson 2

Discuss first the different explanations the students come up with from their homework. Group the student explanations with the observations they are trying to explain. Do not comment on the correctness of the explanation.

e) *Why is the outside surface of beaker A colder than the outside surface of beaker B?*
f) *Why does ice melt faster in liquid A than in liquid B?*
g) *Why does moisture appear on the outside surface of beaker A but not on beaker B?*
h) *Why does a white cotton-like substance form around the ice in beaker B?*

For example, question e) might be related to g) and could be explained by:

e1: *In beaker A ice readily absorbs heat from the liquid and its container whereas in beaker B absorption of heat is obstructed by the presence of the cotton like substance around the ice;* and/or

e2: *The liquid in beaker B may be a poor conductor of heat;*

g1: *Water vapor in the air condenses rapidly on the outside surface of beaker A forming moisture because of the very low temperature of the container.*

Student explanations are grouped according to similarities. Groups of students are assigned to design verification experiments for the different explanations. This could be continued as homework.

Lesson 3

Groups present the designs for the verification experiment. Then equipment is distributed. Students then carry out their experiments. To investigate explanations e1, e2, and g1 students could:

1. Take the initial temperatures of water and of oil.
2. Repeat the starter experiment.
3. Take 10 temperature readings in both containers at intervals of 10 seconds.
4. Compare the temperature readings near the ice and near the glass in both containers.

Similarly students would have alternative explanations for the other questions (a-h listed above) and procedures could be designed for verification/ falsification experiments. For example, question h) might elicit an explanation involving the freezing of oil around the ice. One could investigate this further by dipping a test tube with oil in an ice bath and observing whether a similar cotton like substance forms. Then students could prepare for reporting their results in a presentation to the class.

Lesson 4

Different groups report to the class and then time is spent on concept formulation (for example, formulating propositions which involve the basic concepts). Finally in the lesson or in homework students write an individual summary of the steps carried out during the last four sessions.