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THE WONDER OF SEEDS—SPROUT INVESTIGATION **Inquiry Teaching and Assessment Guide**

The National Science Education Standards (NRC, 2000) describes inquiry in education in the following way:

“Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical logical thinking, and consideration of alternative explanations.”

In teaching at the undergraduate level, we have before us the model of how we were taught while at university. That model usually means attending lectures and participating in laboratory sessions. Lectures generally place students in a passive learning role. They are lectured “at” by the expert. This model of teaching looks at the students as an empty vessel to fill with knowledge provided by an all-knowing teacher. The laboratory is most often a cookbook exercise with the exercise duplicated by individual or pairs of students. Emphasis is on skill development. The written lab report is often a rote exercise that students do not fully appreciate as one that is done for a real purpose by scientists in their everyday conduct of science. Although these types of lectures and labs are not universal in American universities and colleges, they are far too prevalent.

Inquiry takes a more constructivist perspective of learning science. That is, understanding is constructed through the multifaceted activities described in the NSES definition quoted above. Instructors are true facilitators of learning. They guide the process by which students come to a deeper understanding of scientific concepts and the connections that bind them. Through this process, students also come to acquire a built-in sense of the inquiry process as described above, as they move from stage to stage as a learner. This description of learning through inquiry begs the question of how instructors as facilitators of inquiry learning can accomplish this.

This guide is directed toward what goes on in the lab classroom. Below are some ideas and pointers on inquiry teaching that might be helpful. Each is written in the context of the inquiry definition provided above.

On perspective: Inquiry teaching is student-centered, not teacher-centered. Focus is placed on what the student knows, how they have come to know it, and how to add new understanding to that existing framework. So let the students lead the way by explaining their understanding. You will guide them to the next step through careful, thoughtful questioning based on what you know their current understanding is. Your job is not to



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dump “right answers” on their doorstep, but to lead them gently on a journey of many twists and turn toward at their own explanations, which will generate the new understanding. Let the student lead their learning by generating their own research questions as much as possible.

Do not be tempted to give away the punch line! Facilitate the process toward the punch line! (This is redundant, but terribly important).

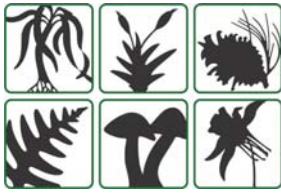
On conducting class discussions: Classroom discussions in which students reveal their thinking are critical. This is when you find out what a student knows and how they have come to know it. The instructor’s job is to pose good questions in a non-threatening way, actively listening to the student’s response and judging how the facile student is with careful reasoning and use of evidence in their explanations. Depending on the purpose of the discussion, which you as the instructor determine, you may be seeking baseline data at the beginning of a session or closing discussion about the meaning and understanding of students about the scientific content and about their ability to integrate the pieces on inquiry into their explanations and communications. Examples of how to conduct discussions are provided in the lesson itself.

On assessment: Assess for the components in the inquiry definition. Do it often throughout the course of the investigation. If students are working in research teams, circulate from team to team, ask questions and follow the rule for classroom discussions above. In classroom discussions to elicit students’ current level of understanding, you will be doing a form of baseline assessment through your questions and probing of their responses. More on assessment below.

Assessment in Inquiry

Inquiry-based teaching looks at assessment through two lenses. The first lens is that of everyday feedback. The second lens is that of what the student has learned at the end of the lesson.

Everyday feedback has been shown to improve student-learning outcomes. As its name suggests, everyday feedback is conducted everyday. It can take place in the context of the whole class, cooperative student teams, and with individual students. The purpose of everyday feedback is to hear student thinking on a topic or construct, understand a student’s framework or model for that construct, and help student’s move along in their thinking. During this process, student misconceptions (sometimes referred to as alternative frameworks) are revealed. Knowing a student’s framework gives teacher’s a wonderful opportunity to guide students to more productive ways of thinking (without giving away the “right answer”).



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Teacher feedback helps students solidify their thinking about which path to take. Teacher feedback is not that the teacher provides an “answer”. Teacher feedback is skillful questioning that promotes student self-reflection on thinking and reasoning. It is a particularly good way of getting insight into your students’ thinking. Questions should be non-threatening in nature. Examples of question starters are:

- Hmm. That’s interesting. ...
 - How do you know that...?
 - What makes you think that....?
 - Did you read about that somewhere....?
 - What is your evidence that....?
 - How can we take that big questions and turn it into a “how” question?
 - Let’s look at whether your observation is consistent with...k
 - I’m not quite sure of the details of what you’re saying. Can you give me an example?

In this investigation, we suggest using the online forums of the team journal, student journal and preliminary lab report as venues for written everyday feedback. The whole-class pre-engagement and exploration phases also provide an excellent panoramic view of student thinking. Using the whole class discussions, teachers can provide instantaneous feedback to expedite student thinking about the topic at hand.

One assessment strategy that can serve both masters of everyday feedback and the ‘end-of-investigation’ feedback is student production of a flipbook document observed changes in seeds as they germinate and develop into sprouts. Flipbook pages should be quite small (a template is provided). The “Captain Underpants” books by Dave Pilkey have sections that are cartoon flipbooks. These books are readily available at bookstores and libraries. Each square in the template is a page in the flipbook. On each page from front to back, students should draw the way the seed/seedling looks on each successive day. Page 1 shows the seed on day one; page 2 on day 2, etc. Along with each flipbook page, the students should journal their observations using the online journal. As each day progresses, the teacher can provide students with feedback as to their observations. Are they accurate? Could they use more detail? Should they focus on structure a little more or less? This feedback will guide students in observing more carefully and powerfully. Careful observation is an incredibly important skill in biology, which has its roots as a descriptive science! Careful observation is also one of the facets of inquiry (refer to inquiry definition). Alternatively, students can provide drawings of seeds and seedlings with narrative descriptions of what they see and the changes they have observed. Students should do these on a daily basis because changes occur very rapidly.

Of special importance is that each student contributes to the team effort. We have embedded in the Student Research Guide ways of identifying who contributes and at what level. If students are not accustomed to this type of experience, it may take them a while to become comfortable with contributing as part of a team. Take this into



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consideration. Give teams feedback as to the need for teamwork and that one student should not dominate the thinking and discussions.

The experimental design itself is a good measure of the “posing questions; examining books and other sources of information to see what is already known; planning investigations”. The final lab report assesses “using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions”.

The ‘end-of-investigation’ content assessment can rely on the debate, poster and individual student model for seed germination and/or assessment. The student needs to provide a model for what their evidence says about how seeds “sprout”. To accomplish this, students can produce a description or concept map of their model for seed “sprouting”. The model should reflect the evidence. This should be part of the poster. If they use evidence from another group’s experiments, they should cite that group’s work just as scientists must cite the work of their colleagues.

To assess how well students can apply their evidence and explanation to a bigger picture, a class discussion can be carried out. In this discussion, students should attempt to put the experiments done by different teams into a class model as much as is possible. Their explanations may then have to be modified to fit the bigger picture. There undoubtedly will be many gaps and even conflicts in the class model. These gaps and conflicts should make students propose new questions to begin resolving them. This process of model-building as an assessment tool and proposing of new research questions again are part of the inquiry definition.

The poster and presentation of the poster to the class in combination of class discussions about the data and their meaning serves to assess communication and teamwork skills.

In addition to assessing content areas, inquiry skills should also be assessed. This can be done in the context of the student him or herself and in the context of what others observed. Use the “Inquiry Assessment Tool” (attached) to help students self-assess and evaluate peers.



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MAKING A FLIP BOOK OF A SEED SPROUTING

- Each box is a page in your flipbook.
- Cut along the dotted lines to separate pages.
- On each page, draw the way your seed looks on each day. You don't have to be an artist to do this. Just draw what you see as best you can, but make sure your drawings show the changes you observe.
- When your investigation is completed, you can staple your pages together. Day 1 goes in the front, day 2 next and so on, until you get to the end of your investigation. (You can also put your book together at the beginning and draw directly in the book. This is helpful if you want to see how your book "flips" before you get to the end of your investigation. If you mess up a drawing, just rip it out of your book and use the next page. Add more pages as necessary.)

REMEMBER!

Scientists use CAREFUL observations as data, so make your drawing detailed enough so that someone looking at the drawing notices changes that you observe.



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Conducting the Classroom Reflective Assessment Discussion

After students have given each poster presentation, the teacher can ask students in the audience to rate the students' presentation. Students will usually be generous giving scores of 3-5 on a 5-point scale (scale below). Ask students to justify their rating using examples, just as a good scientist uses evidence to support their models.

Here is a sample classroom assessment discussion from the ThinkerTools research project from which this protocol was obtained. The teacher picked a few of the assessment criteria and asked the students in the audience to rate the students' presentation. The rating scale is:

- 1 = not adequate
- 3 = adequate
- 5 = exceptional

Assessment criteria:

- Understanding the Science
- Understanding the Process of Inquiry
- Making Connections
- Being Inventive
- Being Systematic
- Using the Tools of Science
- Reasoning Carefully
- Writing and Communicating Well
- Being a Good Team Player
- Assessing Myself

Teacher: OK, now what we are going to do is to give them some feedback. What about their understanding of the inquiry process? In terms of following the steps within the Inquiry Cycle, on a scale of 1 to 5, how would you score them? Vanessa.

Vanessa: I think I would give them a 5 because they followed everything. First, they figured out what they wanted to inquire, and then, they made hypotheses, and then they figured out what kind of experiment to do, and then they tried the experiment, and then they figured out what kind of experiment to do, and then they tried the experiment, and then they figured out what the answer really was and that Jamal's hypothesis was correct.

Teacher: All right, in terms of their performance, "being inventive." Justin?

Justin: Being inventive. I gave them a 5 because they had completely different experiments than almost everyone else's I've seen. So, being inventive, they definitely were very inventive in their experimentation.



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Teacher: OK, good. What about “reasoning carefully?” Jamal, how would you evaluate yourself on that?

Jamal: I gave myself a 5, because I had to compute the dotprints between experiments [interpolate] we did on mass. So, I had to compute everything. And, I double checked all of my work.

Teacher: Great. OK, in terms of the social context of work, “writing and communicating well.” Carla, how did you score yourself in that area?

Carla: I gave myself a 4, because I always told Jamal what I thought was good or what I thought was bad, and if we should keep this part of our experiment or not. We would debate on it and finally came up with an answer.

Teacher: What about “teamwork”? Does anyone want to rate that? Teamwork. Nisha.

Nisha: I don't know if I can say because I didn't see them work (laughter).

Teacher: That's fine. That's fair. You are being honest. Julia.

Julia: I gave them a 5 because they both talked in the presentation, and they worked together very well, and they looked out for each other.