SCAFFOLDING SCIENCE INQUIRY INSTRUCTION

Scaffolding instruction as a teaching strategy originates from Lev Vygotsky’s sociocultural theory and his concept of the *zone of proximal development* (ZPD). “The zone of proximal development is the distance between what children can do by themselves and the next learning that they can be helped to achieve with competent assistance” (Vygotsky, 1978, 86).

The activities provided in scaffolding instruction are just beyond the level of what the learner can do alone. An important aspect of scaffolding instruction is that the scaffolds are temporary. As the learner's abilities increase the scaffolding provided by the more knowledgeable other is progressively withdrawn. Finally the learner is able to complete the task or master the concepts independently. Therefore the goal of the educator when using the scaffolding teaching strategy is for the student to become an independent and self-regulating learner and problem solver.

The scaffolds provided are activities and tasks that:
1. Motivate or enlist the student’s interest related to the task
2. Simplify the task to make it more manageable and achievable for a student
3. Provide some direction in order to help the child focus on achieving the goal
4. Clearly indicate differences between the student’s work and the standard or desired solution
5. Reduce frustration and risk
6. Model and clearly define the expectations of the activity to be performed (National Research Council, 2004).

In the classroom setting, scaffolds may include models, cues, prompts, hints, partial solutions, think-aloud modeling and direct instruction (Hartman, 2002). Teachers may also use questions as scaffolds to help students solve a problem or complete a task. By increasing the level of questioning or specificity, the student will be able to provide a correct response and comprehend the concept targeted. Thus, students are guided and supported through questioning and learning activities that serve as interactive bridges to get them to the next level.

Research has found out that scaffolding is an effective teaching strategy for scientific inquiry and experimentation (external representations – graphs, tables, etc.). The use of external representations, representational scaffolds, can serve as an effective strategy for teaching these scientific skills. For example, teachers may provide a teacher-specified table of variables first as a scaffold. Then, students need to select the appropriate variable related to their experiment. This may help students abstract the overall structure of the experiment and thus aided their understanding of the experimental design. This would help the students learn what things must be considered when designing an experiment.

Two major steps in instructional scaffolding in science inquiry:
- Development of plans to lead students from what they know to a deep understanding of new concept or material.
- Execution of those plans, where the teacher supports the students at every step of the inquiry process.
Scaffolding inquiry experiences

Teachers should vary the amount of guidance in their inquiry-based teaching, from “Developing” to “Exemplary,” depending on student skills and needs. These different levels of variation can be used by applying the framework in Figure 1—the five essential features of classroom inquiry and their variations of “openness.” Teachers can successfully start using teacher-directed inquiry (right-hand column in the Table) and work up to variations of inquiry that are more open and student-directed (left-hand column).

<table>
<thead>
<tr>
<th>Essential Skills</th>
<th>Developing Inquiry</th>
<th>Proficient Inquiry</th>
<th>Exemplary Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (Questions) Learner engages in scientifically oriented questions</td>
<td>Teacher <strong>directly presents or provides</strong> questions for investigation</td>
<td>Teacher uses guiding questions, experiences, and/or feedback to <strong>help students differentiate</strong> scientific versus non-scientific questions</td>
<td>Teacher helps <strong>students formulate</strong> scientific questions, testable scientific questions, or scientific questions that are specific</td>
</tr>
<tr>
<td>2. (Investigate) Learner gives priority to evidence in responding to questions</td>
<td>Teacher identifies, defines, and describes variables in a scientific investigation, or data collection procedures</td>
<td>Teacher guides students to differentiate between dependent and independent variables in a scientific investigation</td>
<td>Teacher helps students: a) specify/use relevant variables for their scientific investigation, b) design and implement appropriate procedures</td>
</tr>
<tr>
<td>3. (Explain) Learner formulates explanations from evidence</td>
<td>Teacher presents or identifies patterns and relationships in data, explanations, or verification/refutation of hypothesis using results.</td>
<td>Teacher guides students to identify patterns and relationships in <strong>provided data</strong>, or differentiate between explanations that are based on evidence and those that are not.</td>
<td>Teacher guides students to identify patterns and relationships in <strong>their data</strong>, or provide underlying reasoning when proposing an explanation for their results</td>
</tr>
<tr>
<td>4. (Communicate) Learner communicates and justifies explanations</td>
<td>Teacher provides no opportunities for students to work in groups and communicate and discuss their investigations and findings.</td>
<td>Teacher models processes and underlying communication rationale to help students understand how to communicate interpretation of results.</td>
<td>Teacher systematically provides opportunities for students to work in groups and communicate and discuss their investigations and findings.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Less</th>
<th>Amount of Learner Self-Direction</th>
<th>More</th>
</tr>
</thead>
<tbody>
<tr>
<td>More</td>
<td>Amount of Direction from Teacher or Material</td>
<td>Less</td>
</tr>
</tbody>
</table>

*Adapted from Teacher Inquiry Rubric (Nugent, 2012)
SCAFFOLDING STRATEGIES IN ENGAGE PHASE

1. What types of titles might spark interest in the concept?
Stimulate students’ curiosity by rephrasing the lab title as a focus question and using it as an engagement. For example, using the introductory phrase “Today we will be looking at the erosive effects of water on Earth materials” or relying on the lab title “Water Changes Our Earth” elicits little or no curiosity from students. Focus questions that convert the title might read, “How do you think water can change the surface of the Earth?”; “What do you think occurs when large amounts of water flow over Earth materials?”; “How could you clean up an oil spill?”; “What are some ways to classify matter?” or “How do geologists identify minerals?”

2. Observation or Demonstration first
To begin the lesson, the teacher presents the class with a discrepant/interesting event in the form of a lab demonstration. Students are told to focus their attention on making observations. Statements such as “use your senses carefully, as each of you will need to repeat this” or “observe how this behaves because I am going to ask you to make it behave differently” can help students focus.
After the demonstration, have students return to their seats to think for a few moments about what they have seen or share observations with a partner or small group. The power of this method is that the ideas are coming from students. The teacher does not tell them what they have seen—or what they should have seen. It is important that all observations come from the students and are framed in their own language. It is a time to honor student thinking and listen to their conversations as they debate what they did or did not observe.

3. Sharing Students’ Observations and Questions
(Observations Starburst Diagram can be used) Ask the students to share what they observed and the questions they have. A teacher could write on the board: “What we observed…” and “Questions we have . . .” Ideally, the class will fill the board with questions and descriptions of what they observed. If students get stuck, prompt their thinking by asking a question such as “Here you ask about the effects of different …substance. What else could you change?”

Example Class 01)
The first week of our tree unit, I took my students outside with clipboards and instructions to write what they noticed and what they wondered about trees. Altogether, they generated almost two dozen questions. “How come the roots don’t show?” “How do trees eat?” “Why are they all so different?” “How do the nests get there?” I was excited by my students’ enthusiasm for generating their own questions, but I was anxious about what to do next. The next day, I announced to my students that we would begin our inquiry journey with an interesting question about trees that many of them shared: Why do leaves change color? As students turned and talked with a partner, I listened in and heard them connecting this question to their prior experiences and knowledge, and to what they had observed during our previous week’s science walks.
**Example Class 02)**

Today Mr. Gilbert plans to introduce his students to the study of the phases of the moon. He begins the lesson by asking his students to write down everything they know about the moon, together with the questions that they have about the moon. He then asks them to discuss their lists with a partner, making note of the items that are included on both lists. Following these discussions, Mr. Gilbert asks his students to compile their lists into one class list of what they know about the moon, and another class list of questions they have about the moon.

<table>
<thead>
<tr>
<th>Things We Know About the Moon</th>
<th>Questions We Have About the Moon</th>
</tr>
</thead>
<tbody>
<tr>
<td>The moon changes shape.</td>
<td>How can the moon be visible during the day?</td>
</tr>
<tr>
<td>The moon is smaller than the earth.</td>
<td>Why don’t eclipses happen more often?</td>
</tr>
<tr>
<td>People have walked on the moon.</td>
<td>What causes the moon’s phases?</td>
</tr>
</tbody>
</table>

He asks several students **how they know that the three items in the left column are true.**

**Example Class 03)**

Mr. Hull begins most units with one or more short survey questions to get students to think about the kinds of situations, issues, and ideas they will be investigating for the next few days. Today, at the opening of class, he asked his students: **“What do you think about when you hear the word force?”** Among the responses were: “gravity is a force,” “pushing, like when I push a car,” “a push or a pull on something,” and “making somebody do something they don’t want to.” While students continued sharing their initial ideas, Mr. Hull wrote the ideas on the board. As he wrote, he organized the ideas into two categories: kinds of forces, and definitions of force (i.e., “force is…”). Mr. Hull wanted his students to be able to represent their understanding of forces, so he guided them in crafting their representations. **He said: “It sounds like several of you are thinking of force as a push or pull. What are some properties of pushes and pulls?”** …

4. **Example Tool:** Observations Starburst Diagram

![Observations Starburst Diagram](image)
SCAFFOLDING STRATEGIES IN EXPLORE PHASE

1. Select the Dependent Variable First for Formulation Hypotheses
(Observations Starburst Diagram can be used) In this activity, the teacher can help students to select one item, which becomes the dependent variable from the shared observations and questions in Engage phase. A class or small group discussion of how to measure changes in the dependent variable—in terms of instruments, units, and techniques—may be helpful at this point, and ideas will vary depending on students’ past experiences. This presents another diagnostic opportunity for the teacher to reflect on the vocabulary and phrasing students use for a specific measuring technique or task. The teacher may want to introduce a new device or procedure for students to consider.

2. Organize Variables for Designing an Investigation
(Fishbone Experiment Organizer can be used) After a dependent variable is selected, you can have student discuss how to measure the DV, what to do with other variables, what they need to collect the data in a small group or class discussion. If you use the Brainstorming Organizer, the students can move the selected DV to the oval labeled “DV” on the Fishbone Experiment Organizer. With a teacher’s guiding questions, student groups write or state a clear hypothesis in “If…then…” form. For example “If the number of candles [independent variable] is increased [or decreased], then the water level [dependent variable] in the jar will increase [or decrease],” or “If the water level in the pan is doubled, then the water level in the jar will decrease by half.”

3. Data-collection table
Requiring student groups to create their own data-collection tables is a good way for the teacher to ensure that students are ready to proceed. He or she may model a data-collection table for the class, but ultimately, student groups should create their own tables. Instead of a worksheet on which students are told what to record and in what format, the students can discuss these issues and decide how to organize and report their observations and conclusions. The absence of a preordained handout may frustrate some students who have been trained to follow “cookbook” activities.

4. Interact with students
While students are conducting their investigations, a teacher moves around observing, listening, and asking questions concerning individual methods and reasoning. In a lab setting, students reveal their conceptions and beliefs by what they do and say. Often what students do does not reflect what they say and may expose weaknesses or conflicts in their current conceptual frameworks. With well phrased teacher questions, students see discrepancies in their thinking, and consider alternatives without being told exactly what to do. With the exception of unsafe practices, teachers must avoid judging students’ ideas, and instead pose questions that mentally engage students in the content and process under scrutiny. At times, students simply ask whether they are right and these requests for teacher authority can be circumvented by asking questions like “How will that step provide the information you want?” or “What difficulties do you expect with the procedure you have developed?” These
provide a window into students’ thinking that can be used by teachers to structure further questions.

**Example Tool 01: Fishbone experiment organizer**

![Fishbone Diagram](image)

CV: Control variables, IV: Independent Variables, DV: Dependent Variables
I: Instrument, U: Units, T: Technique for measurement

**Example Tool 02: Four Question Strategy**

Choose a topic you are interested in doing experiments on: ________________, and then write the topic in the blanks to questions 1-4.

1. What materials are readily available for conducting experiments on ____________?
2. How do __________ act?
3. How can I change the set of __________ materials to affect the action?
4. How can I measure or describe the response of __________ to the change?

Example

1. What materials are readily available for conducting experiments on Plants?
   - Soils
   - Plants
   - Fertilizers
   - Water
   - Light/Heat
   - Containers
   - Seeds

2. How do Plants act? •Plants Grow •Wilt •Flower

3. How can I change the set of Plants materials to affect the action?

<table>
<thead>
<tr>
<th>Water</th>
<th>Plants</th>
<th>Containers</th>
<th>Soil</th>
<th>Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>•Amount</td>
<td>•Spacing</td>
<td>•Location of holes</td>
<td>•Composition</td>
<td>•Size</td>
</tr>
<tr>
<td>•Scheduling</td>
<td>•Kind</td>
<td>•Number of holes</td>
<td>•Amount</td>
<td>•Color</td>
</tr>
<tr>
<td>•Source</td>
<td>•Age</td>
<td>•Shape</td>
<td>•Depth</td>
<td>•Number</td>
</tr>
<tr>
<td>•Composition</td>
<td>•Size</td>
<td>•Material</td>
<td>•Compaction</td>
<td>•Planting depth</td>
</tr>
<tr>
<td>•pH</td>
<td></td>
<td>•Size</td>
<td></td>
<td>•Age</td>
</tr>
</tbody>
</table>
4. How can I measure or describe the response of Plants to the change?
   • Count the number of leaves
   • Measure the length of the longest stem
   • Count the number of flowers
   • Mass (weight) of the fruit produced
   • Measure the diameter of the stems

**Experimental Design using the Four Question Strategy**

• Hypothesis: If I change (an independent variable from question 3), then the (dependent variable from question 4) will change.
• Independent Variable (selected from question 3)
• Dependent Variable (selected from question 4)
• Constant variable: Except for the one selected all the potential variables listed as a response to question 3 become constants for the experiment.

Example Product:
**Independent Variable**: Amount of Fertilizer (5g increments)
**Dependent Variable**: Height of Plants
**Constants**: Except for Fertilizer all potential variables listed as responses to question 3 become the constants for this experiment
**Hypothesis**: If the amount of fertilizer is changed, then the height of the plants will change.

**SCAFFOLDING STRATEGIES IN EXPLAIN PHASE**

1. **Small Group Discussions**
   The next step (after appropriate cleanup) is for student groups to write their results on the board or on chart paper. Seated in groups, students are formulating collective responses to a focus question written on the whiteboard. The results will be very messy! Groups may have selected different research questions, used a different number of trials, or recorded data in different formats. This is the ideal time to discuss how we can make sense of the information. Students will realize that some formats (such as a table) are easier to read than others.
   • Have students refer their original hypotheses and then highlight the part of the hypothesis that their data can best speak to.
   • Have the students work in groups to summarize their 2-3 key findings from their studies. They should focus on the pieces of their data that support, refute or add to what is already known. This means that the students should also write down 2-3 statements that their theory or model would support or predict. Help the students write these statements in the simplest way possible. Then have the students draw lines that connect the statements from their findings with their statements from their models.

2. **Class wide Discussions**
   In addition to analyzing data, students must also communicate and explain their results. Each group should prepare a **data table, graph, concept map, or other visual representation** showing their results and any relationships derived from the data. This can be presented to the
class as a poster or PowerPoint presentation or through individual lab reports. Students should work together to come up with scientific explanations based on their observations. The Explain lesson provides opportunities for students to connect their previous experiences with current learning and to make conceptual sense of the main ideas of the module. This stage also allows for the introduction of formal language, scientific terms, and content information that might make students’ previous experiences easier to describe. A class wide discussion should encourage students to:

- Explain concepts and ideas (in their own words) about the topic
- Listen to and compare the explanations of others with their own
- Become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas
- Revise their ideas
- Record their ideas and current understanding
- Use labels, terminology, and formal language
- Compare their current thinking with what they previously thought.

3. Concept Development

Effective scaffolding leads students’ investigation to conclusions and explanations as students work through the lessons. However, the concept has not been explicitly presented until the Explore phase. Following questioning strategies helps students develop an understanding of the concept.

- During the discussion, ask students to demonstrate their understanding by using following questions
  a. How do you know…?
  b. Where did you get…?
  c. Why did you do…?
  d. What does…tell you?
  e. What does…mean?
  f. Where on your (graph, table, diagram, etc.)…?
- Introduce the scientific terms/names/concepts after the students demonstrate the pattern/concept. Or,
- **Use Revoicing strategies** in the form of rephrasing, summarizing, elaborating, or translating their responses. It allows the teacher to introduce key terms in the students’ contribution.
- Ask students to use the terms to express their explanation and conclusions. At this point, additional information and a name for the concept then can be introduced.
- Although teachers may be the ones to introduce the name (so that standard language is used), make it clear that it is the students who discover the patterns.
- Teachers need to practice expressing the concept in students’ words, and identify key points that can be indicators of understanding
- Develop several types of questions that check understanding of the key points
References