As an instructional approach, scientific inquiry receives widespread support from educators. Although there is consensus that students should have the opportunity to investigate the natural world as scientists do, many factors interfere with this approach becoming commonplace in the science classroom. For example, teachers’ lack of knowledge about or experience with inquiry is a common stumbling block (Roehrig and Luft 2004).
One way to advance inquiry in the classroom is to establish a systematic strategy for reflecting on our practice and our students’ readiness to engage in increasingly complex scientific reasoning. The Matrix for Assessing and Planning Scientific Inquiry (MAPSI; Figure 1, pp. 34–35) is a tool that promotes this valuable reflection so that we, as teachers, are better equipped to engage students in inquiry. This article describes the MAPSI tool and how it was used to plan inquiry experiences in a high school biology class.

**About inquiry**

When students conduct scientific inquiries, they engage in those cognitive processes, interactions, and skills reflected in the work of scientists. This process is summarized in the description of inquiry put forth by the National Science Education Standards:

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 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 and logical thinking, and consideration of alternative explanations (NRC 1996, p. 23).

The National Research Council (NRC 2000) encourages teachers to shift the responsibility for inquiry to the learner—reducing support from the curriculum materials and the teacher.

**About MAPSI**

Although there are tools to help plan and implement inquiry (Bell, Smetana, and Binns 2005; NRC 2000; Volkmann and Abell 2003), MAPSI allows teachers to unpack the cognitive processes and scientific reasoning tasks associated with this instructional approach. MAPSI describes these tasks along a continuum organized around four levels of complexity for four cognitive processes and their subsequent subprocesses (Figure 1). These processes include:

1. generating scientifically oriented questions,
2. making predictions or posing preliminary hypotheses,
3. designing and conducting the study,
4. and explaining results.

MAPSI, a modification of a tool designed by Dolan and Grady (2010), was inspired by the National Research Council’s “Essential Features of Classroom Inquiry and Their Variations” (NRC 1996, p. 28 in this issue) and Chinn and Malhotra (2002). Figure 2 (p. 36) shows part of a MAPSI developed for an inquiry about factors that affect healthy plant growth and development. (The full MAPSI for this activity is available “On the web.”)

Cognitive complexity increases as students take on more responsibility (i.e., reasoning and decision making). Teachers can personalize their use of MAPSI for their intended science domain, student population, required curriculum, and lesson goals, and other factors that influence instructional decisions—making it a helpful planning tool.

**Using MAPSI**

Although there is no prescribed strategy for using MAPSI in the classroom, it is helpful to begin by assessing students’ current practice. This can help teachers identify areas of student strengths, which can, in turn, help them recognize needs for future investigations that allow students to experience more complex reasoning.

Colburn (2008) and Bell, Smetana, and Binns (2005) recommend that inquiry be scaffolded so that students gradually assume more responsibility as they engage in reasoning that is increasingly complex. Once teachers have assessed the complexity level of existing activities, they can use MAPSI to plan future inquiries so that students are gradually able to engage in more complex reasoning.

When students are ready for this shift, it is important that teachers are prepared to facilitate their engagement with more complex tasks. MAPSI can help teachers pinpoint the cognitive processes and subprocesses they need to learn more about and those they are already comfortable using with students. By determining their own readiness to support students, teachers can better plan successful inquiries to scaffold students’ experiences.

In addition to evaluating student and teacher readiness, MAPSI is also useful for revising simple inquiry investigations. Teachers can plan modifications to existing activities that increase students’ responsibility for the inquiry. As a result of this planning, teachers are able to recognize the support they need to provide students as the responsibility shifts. This support will be context-specific and vary for different inquiries.

**A classroom scenario**

Fran (not her real name), a novice biology teacher at a rural high school, wanted to engage her students in an investigation to address the state-mandated curriculum on the nature of science and plant growth and development. Instead of following the “cookbook” lab format her students were...

<table>
<thead>
<tr>
<th>Cognitive processes</th>
<th>Scientific reasoning tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Least complex</strong></td>
</tr>
<tr>
<td>1. <strong>Generating scientifically oriented questions</strong></td>
<td>Students do not contribute to the investigation question; the question is provided by the teacher or curriculum materials.</td>
</tr>
<tr>
<td></td>
<td>Students make small revisions to the investigation question based on questions provided by the teacher or curriculum materials.</td>
</tr>
<tr>
<td>2. <strong>Making predictions or posing preliminary hypotheses prior to conducting investigations</strong></td>
<td>Students do not pose preliminary hypotheses or make predictions; hypotheses and predictions are provided by the teacher or curriculum materials.</td>
</tr>
<tr>
<td></td>
<td>Students choose from possible predictions or preliminary hypotheses provided by the teacher or curriculum materials.</td>
</tr>
<tr>
<td>3. <strong>Designing and conducting the research study</strong></td>
<td>Students do not contribute to the design of the investigation; the procedure is provided by the teacher or curriculum materials.</td>
</tr>
</tbody>
</table>

**Subprocesses**

<table>
<thead>
<tr>
<th>Subprocess</th>
<th>Least complex</th>
<th>Most complex</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designing the procedure for the investigation</strong></td>
<td>Students do not contribute to the design of the investigation; the procedure is provided by the teacher or curriculum materials.</td>
<td>Students make limited contributions to the procedure.</td>
</tr>
<tr>
<td><strong>Selecting dependent and independent variables</strong></td>
<td>Students do not choose variables; variables are chosen by the teacher or curriculum materials.</td>
<td>Students make numerous contributions to the procedure.</td>
</tr>
<tr>
<td><strong>Considering experimental controls and conditions that need to be controlled</strong></td>
<td>Students give no attention to the design of controls, and conditions that need to be controlled are provided by the teacher or curriculum materials.</td>
<td>Students make minimal attention to the design of controls and conditions that need to be controlled.</td>
</tr>
<tr>
<td><strong>Gathering and organizing data during the investigation</strong></td>
<td>Students do not collect data; the data is provided by the teacher or curriculum materials.</td>
<td>Students gather and record their own data, giving thoughtful consideration to the representations of the data with little to no contribution from the teacher.</td>
</tr>
<tr>
<td></td>
<td>Students gather and record data, giving little to no thought to the representations (e.g., tables, drawings, or photos) of the data.</td>
<td>Students gather and record data, giving some thought to the representations of the data with some contributions from the teacher.</td>
</tr>
</tbody>
</table>
### 4. Explaining results

<table>
<thead>
<tr>
<th>Subprocesses</th>
<th>Students do not analyze data; the data analysis is provided by the teacher or curriculum materials.</th>
<th>Students conduct some of the data analysis; much of the analysis is done by the teacher.</th>
<th>Students conduct their own data analyses with some contributions from the teacher.</th>
<th>Students conduct their own data analyses with little to no contribution from the teacher.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analyzing data using calculations, graphing, and statistical analyses; looking for anomalous data</strong></td>
<td>Students do not identify evidence from the data; the teacher or curriculum materials identify the evidence.</td>
<td>Students identify the evidence from the data; much of the analysis is done by the teacher.</td>
<td>Students identify the evidence from the data; some contributions to the analysis are done by the teacher.</td>
<td>Students identify the evidence from the data with little to no contribution from the teacher.</td>
</tr>
<tr>
<td><strong>Identifying the evidence from the analyzed data</strong></td>
<td>Students do not provide explanations; the teacher or curriculum materials provide the explanations.</td>
<td>Students provide explanations with significant contributions from the teacher.</td>
<td>Students provide explanations with some contributions from the teacher.</td>
<td>Students provide explanations with little to no contribution from the teacher.</td>
</tr>
<tr>
<td><strong>Providing explanations; noting unexpected findings; addressing accuracy of data, experimental errors, limitations, or flaws</strong></td>
<td>Students do not connect the evidence to scientific knowledge; the teacher or curriculum materials provide the connections.</td>
<td>Students make the connections between the evidence and scientific knowledge with significant contributions from the teacher.</td>
<td>Students make the connections between the evidence and scientific knowledge with some contributions from the teacher.</td>
<td>Students make the connections between the evidence and scientific knowledge with little to no contribution from the teacher.</td>
</tr>
<tr>
<td><strong>Connecting evidence with scientific knowledge</strong></td>
<td>Students do not address alternative explanations for evidence or predictions; the teacher or curriculum materials provide alternative explanations and predictions.</td>
<td>Students pose alternative explanations and predictions with significant contributions from the teacher.</td>
<td>Students pose alternative explanations and predictions with some contributions from the teacher.</td>
<td>Students pose and analyze alternative explanations and predictions with little to no contribution from the teacher.</td>
</tr>
<tr>
<td><strong>Posing and analyzing alternative explanations and predictions</strong></td>
<td>Students do not communicate and defend their findings; the teacher communicates the findings to the students.</td>
<td>Students communicate and defend their findings with significant contributions from the teacher.</td>
<td>Students communicate and defend their findings with some contributions from the teacher.</td>
<td>Students communicate their findings with little to no contribution from the teacher. Students use logical arguments to defend their findings.</td>
</tr>
<tr>
<td><strong>Communicating and defending findings through discussion, presentations, or written reports</strong></td>
<td>Students do not analyze data; the data analysis is provided by the teacher or curriculum materials.</td>
<td>Students conduct some of the data analysis; much of the analysis is done by the teacher.</td>
<td>Students conduct their own data analyses with some contributions from the teacher.</td>
<td>Students conduct their own data analyses with little to no contribution from the teacher.</td>
</tr>
</tbody>
</table>
accustomed to, she decided to provide them with the over-
arching research question—“What factors affect the healthy
growth and development of plants?”—and the freedom to
design and direct their own investigations. Beyond this, she
gave little consideration to how the inquiry would proceed.
The subsequent confusion and chaos in the classroom—the
result of moving from teacher-directed to student-directed
laboratory activities in one leap—convinced her that inquiry would not
work for her students.

However, the next school year, Fran decided to give the
plant development inquiry one more try. This time, before
introducing the activity to her class, she used MAPSI to
start her planning process and evaluate her students’ overall
readiness to engage in complex reasoning. Fran’s evaluation
included observing students as they worked and listening
to their questions and discussions during laboratory experiences.
Based on her analysis, Fran thought her students were
ready to engage in more complex reasoning than is typically
required in a traditional teacher-directed investigation.

Fran then used MAPSI to evaluate the “cookbook” lab
on plant development she hoped to use as the basis for the inquiry. After assessing the level of reasoning com-
plicity needed to complete the lab, she considered students’
readiness to engage in reasoning at this level. (Fran’s assess-
ment of students’ reasoning complexity and the changes she
made to the investigation using MAPSI are available online
[see “On the web” at the end of this article].)

Fran also thought about her own readiness to support
students in this inquiry. She felt confident that she could do
so because of the context of this particular inquiry—she was
familiar with plants and their development.

However—because of her experience with inquiry the
year before, her lack of confidence in relinquishing some
control to her students, her students’ lack of familiarity
with inquiry, her need to closely align the activity with
the state curriculum, and the pressure she felt to prepare

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**FIGURE 2**

Investigating factors that affect plant development.

*(Note: The full list of scientific reasoning tasks, cognitive process, and subprocesses for this particular inquiry is
available “On the web.”)*

<table>
<thead>
<tr>
<th>Cognitive processes</th>
<th>Examples of scientific reasoning tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Generating scientifically</td>
<td>Least complex: Students are given the research question: “How does the pH of the water used to water plants affect the plant development as reflected in stem length?”</td>
</tr>
<tr>
<td>oriented questions</td>
<td>Limited complexity: Given the research question—“Does the pH of the water used to water plants affect plant development as reflected in the stem length?” —the teacher suggests students choose from pHs of 5, 6, 7, or 8. Students make the following revision to the research question: “How does water of pH 8 used to water plants affect plant development as reflected in the stem length?”</td>
</tr>
<tr>
<td></td>
<td>More complex: Students make revisions to questions provided by the teacher. The teacher provides the following questions:</td>
</tr>
<tr>
<td></td>
<td>• “How does the pH of the water used to water plants affect stem length?”</td>
</tr>
<tr>
<td></td>
<td>• “How does the humidity of a plant’s environment affect leaf surface area?”</td>
</tr>
<tr>
<td></td>
<td>• “How does the plant’s exposure to ultraviolet (UV) light affect leaf color?” and</td>
</tr>
<tr>
<td></td>
<td>• “How does the plant’s exposure to salt water affect the number of flowers produced?”</td>
</tr>
<tr>
<td></td>
<td>The teacher then guides students in making changes to the question to narrow the focus to a particular pH, amount of humidity, exposure to UV light, and amount of salt in the water.</td>
</tr>
<tr>
<td></td>
<td>Most complex: The teacher’s role is limited to guiding students to consider what is safe, practical, and realistic for the investigation. Students generate their own research questions about factors that affect plant development—based on their previous plant experiments and their literature research about plants and factors that influence plant development.</td>
</tr>
</tbody>
</table>
students for the end-of-course test—she decided it might be best to maintain some control over the inquiry but still provide opportunities for students to stretch their reasoning to higher levels.

Taking these factors into consideration, Fran decided to provide students with a limited selection of variables and research questions that they could choose from and then revise—provided the revisions aligned with the overarching question (“What factors affect the healthy growth and development of plants?”) (Figure 2). In the past, making predictions, designing procedures, and gathering and organizing data had been teacher-directed tasks with little student input. But because she felt her students were ready to take on more responsibility, Fran planned for these tasks to be more student-directed.

After determining how to increase the complexity of this inquiry, Fran decided to give students more independence with the stages of the inquiry process that follow data collection. In the past, Fran would have concluded the inquiry with a whole-class discussion, but this time, she decided to guide lab teams—with varying amounts of support—in analyzing data, looking for trends and anomalous data, developing meaningful explanations, discussing accuracy, identifying flaws and limitations, connecting evidence to scientific knowledge, and considering other explanations for the findings. Planning with MAPSI helped Fran realize that these subprocesses were ones she needed to learn more about—as her experience with them was somewhat limited.

Finally, instead of having students submit the formatted report on which they recorded data and answered follow-up questions, she had lab teams generate their own data tables and develop class presentations to inform their classmates about their evidence, explain their conclusions, and defend their explanations based on scientific knowledge about plants (with some help from her).

After implementing the revised inquiry experience in her classroom, Fran used MAPSI to again reflect on the experience, her students’ success engaging in more complex reasoning, her own success in supporting her students, ways to improve the investigation for use with future classes, and why her first attempt fell short. MAPSI also provided her with a visual, decision-making guide for scaffolding students’ inquiry experiences to gradually move them from less to more complex reasoning.

**Conclusion**

Despite the science education community’s emphasis on and support for engaging students in inquiry, it is not the standard instructional practice in high school science classrooms. However, MAPSI moves this target closer for teachers. In addition to helping teachers better understand the cognitive processes and reasoning tasks that typify inquiry, MAPSI is also useful for assessing current inquiry and planning future inquiries that promote increasingly complex reasoning.

As teachers become more comfortable using MAPSI, they can have students use it to assess and plan their own inquiries. Schools may also find MAPSI useful for aligning inquiry across disciplines or grade levels so that students become progressively more responsible for their inquiries and gradually engage in more complex scientific reasoning. ■

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**On the web**


**References**


